LAYOUTS AND OPERATING CRITERIA FOR AUTOMATION OF DAIRY PLANTS MANUFACTURING ICE CREAM AND ICE CREAM NOVELTIES

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CONTENTS

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Layouts and Operating Criteria for Automation of Dairy Plants Manufacturing Ice Cream and Ice Cream Novelties

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SUMMARY

Automated and highly mechanized operating methods and an improved layout can reduce costs for ice cream plants.

It is estimated that labor costs in a plant manufacturing 200,000 gallons of ice cream annually would be about $9,750 less in an automated plant with an improved layout than in a nonautomated plant with a typical layout. The production per man-hour for the automated plant is estimated to be 27.5 gallons and for a nonautomated plant 21 gallons. The estimated cost of the additional equipment required to make these savings possible is $25,000. If 20 percent of this extra cost is added for costs of ownership and costs of operating the equipment, the net saving owing to automation is $4,750.

A larger plant, manufacturing 1 million gallons of ice cream and 250,000 gallons of novelties, can reduce its labor costs $52,000 annually and increase its production from 24 to 35.5 gallons per man-hour by automating and by improving plant layout. The estimated cost of the equipment required to realize these savings is $127,500. If an allowance of 20 percent of the extra cost is added for ownership and operating costs, these costs would amount to $25,500, leaving an annual saving of $26,500.

The reductions in costs brought about by automation are primarily in assembling and processing ice cream mix and in cleaning the equipment.

Layouts were developed for a plant manufacturing 200,000 gallons of ice cream annually and a plant manufacturing 1 million gallons of ice cream and 250,000 gallons of novelties. The layouts show arrangement of equipment for the most efficient flow of products, containers, and supplies through the plants. The layout of each plant provides for future expansion to double the original production.

BACKGROUND OF THE STUDY

Dairy manufacturing is one of the most competitive industries in this country. Automation—remote control of machines and devices and the programing of sequences of operations—is one way of reducing cost without sacrificing quality of the finished product.

In 1958 and 1959 a survey was made of 75 dairy plants of various types and sizes in 30 States, to determine the extent to which automation had been applied to dairy plants and the effect automation had on operating costs. The survey showed that, although mechanization was common, mechanized operations were automated in only a few of the larger plants. The study indicated that plant operators were aware of the need for more efficient handling methods; however, they lacked knowledge on how to automate and under what conditions automation would be feasible.

The manufacturing of ice cream and ice cream novelties involves operations that can be automated.

The purpose of this study is to provide information to operators of ice cream plants to assist them in improving their operating procedures and plant layouts and in making use of automated methods in building new plants and remodeling existing ones. The objectives of the study were to (1) develop plant layouts showing the types and arrangement of equipment essential for automation and highly mechanized operations and (2) show how the plant operates. The report does not attempt to compare actual costs of operation in nonautomated and automated plants. Estimated costs of additional equipment required for an automated plant are based on the author's knowledge and experience in this field.

Two plants were selected to illustrate operat-

[1] The study on which this report is based was conducted and the report prepared by Dr. Tracy under a contract with the U.S. Department of Agriculture. Dr. Tracy was formerly professor of dairy technology, Department of Food Technology, University of Illinois.

ing principles: One manufacturing 200,000 gallons of ice cream annually and the other manufacturing 1 million gallons of ice cream and 250,000 gallons of novelties a year. The plans for the plants illustrate only the principles of layout, design, and size in relation to volume and products manufactured.

The primary objectives of the principles and layouts developed in this study were (1) to reduce the labor required in receiving the mix ingredients and in processing, packaging, storing, and loading out ice cream and novelty products; (2) to maintain the quality of the products manufactured; (3) to remove the drudgery of plant work owing to manual methods or to poorly mechanized methods; and (4) to reduce in-plant loss by automatic control over mix standardization and processing.

Because of the many differences in ice cream production and consumption throughout the country, it was necessary to make certain assumptions to develop the plans for the two plants. For example, local consumer preferences and variations in climate result in marked differences in the seasonal sales of ice cream and ice cream novelties and in the flavors and package sizes sold. There are also differences in the types of milk products that are readily available in different sections of the country. Fresh cream and concentrated skim milk are commonly used to make ice cream in the Eastern and Midwestern sections of the country, where an abundant supply of milk is produced. In certain sections of the Southeast and Southwest, however, most of the milk produced locally is needed for bottling; in such areas, a concentrated form of fat, such as unsalted butter or butter oil, and nonfat solids, such as dried skim milk, are commonly used for making ice cream. Thus, assumptions were made about production and sales schedules, flavors to be manufactured, volume of each of these flavors, container sizes and volume of each flavor to be packaged in each size of container, specific ingredients or formula to be used for each type of mix, and number of days each week to receive ingredients, manufacture the specific items, and load out various finished products.

Ice cream plant operators planning the construction of new plants or the expansion of existing plants should consult engineers, dairy technologists, and local health department officials for assistance in the preparation of actual plant designs.

PLANT MANUFACTURING 200,000 GALLONS OF ICE CREAM A YEAR

Assumptions With Respect to Plant Operations

To illustrate principles of plant layout and methods of operation for an automated ice cream plant annually handling 200,000 gallons of ice cream, ices, and sherbets, we assumed that 90 percent of the production would be ice cream and 10 percent would be ices and sherbets. In addition, we assumed that the plant would handle 30,000 gallons of novelties purchased from outside sources. Receiving novelties is not considered a major operation.

The volume of ice cream manufactured varies by seasons of the year and from month to month. Based on national averages, production is smallest during November, December, January, and February and largest during June, July, and August. The peak production month is July. During this month 11 percent of the annual production is manufactured. Thus, a plant producing 200,000 gallons annually would manufacture about 22,000 gallons of ice cream during July.

The equipment and the layout of a plant should be adequate to meet the peak operating requirements. Assuming that the July production is evenly divided into weeks, the peak weekly production would be 5,500 gallons. It is assumed that the plant would prepare mix ingredients on Monday and Thursday and manufacture ice cream on Tuesday and Friday. Thus, ice cream for the week's needs is produced in 2 days—2,750 gallons each day, of which 2,475 gallons is ice cream and 275 gallons, sherbets and ices.

To manufacture this volume efficiently, a weekly operating schedule is necessary. Table 1 shows the assumed operating schedule for the plant. The plant would operate 5 days a week—Monday, Tuesday, Thursday, Friday, and Saturday. On Monday and Thursday the mix-making, loading-out, cleaning, and maintenance operations would be performed. The receiving of mix ingredients, freezing, packaging, storing, loading-out, cleaning, and maintenance operations would be performed on Tuesday. All these operations, with the exception of receiving mix ingredients, would be repeated on Friday. On Saturday, such operations as loading out, cleaning, maintenance, and receiving mix ingredients would be performed.

The ice cream will have an average overrun (volume added by the incorporation of air into the mix) of 85 percent and sherbets and ices 50 percent. The ingredients used in preparing 1,000 gallons of ice cream mix, sherbet mix, and water ice mix, for the purpose of this study, are shown in table 2. The amount of ice cream mix

TABLE 1.—*An assumed operating schedule by day of week for performing major operations in an ice cream plant manufacturing 5,500 gallons of ice cream a week*

Operation	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Receiving mix ingredients		x				x	
Mix making	x			x			
Freezing		x			x		
Packaging		x			x		
Storing		x			x		
Loading out	x	x		x	x	x	
Cleaning	x	x		x	x	x	
Maintenance	x	x		x	x	x	

TABLE 2.—*Assumed ingredients for 1,000 gallons of ice cream mix, sherbet mix, and water ice mix*

Ingredient	Ice cream mix[1]	Sherbet mix	Water ice mix
	Pounds	*Pounds*	*Pounds*
40 percent cream	2,288.0		
30 percent concentrated skim milk	3,096.0		
Corn sirup (76 percent solids)	384.0	1,000.0	1,000.0
Liquid sugar (67 percent solids)	1,748.0		
Stabilizer	27.5	22.0	22.0
Emulsifier	5.0		
Sugar sirup (67 percent solids)		3,000.0	3,000.0
Ice cream mix (10 percent)		915.0	
Citric acid		43.0	43.0
Water	1,601.5	4,520.0	5,350.0
Total	9,150.0	9,500.0	9,415.0

[1] For a formula of 10-percent fat, 11.5-percent serum solids, 12.8-percent cane or beet sugar solids, 3.2-percent corn sirup solids, and 0.35-percent stabilizer and emulsifier.

required on a day when 2,475 gallons of ice cream is manufactured is 1,337 gallons; for 275 gallons of ices and sherbets, 183 gallons of mix is required.

It is also assumed that the plant would manufacture 12 different flavors of ice cream, sherbets, and ices: Vanilla, chocolate, chocolate ripple, strawberry, butter pecan, coffee, pineapple, peach, and banana ice cream, and orange, raspberry, and pineapple ice and sherbet. However, not all flavors would be produced each manufacturing day.

Twenty-four percent of the ice cream, sherbets, and ices would be packaged in 2½-gallon cans, 62 percent in half-gallon cartons, and 14 percent in pint cartons.

Novelties purchased from other manufacturers would consist of stick items, such as water ice and chocolate-coated bars, chocolate-coated ice cream bars, and 4-ounce cups of ice cream. All novelties would be received in the plant in bags—a dozen items to each bag.

The rate for freezing ice cream, sherbets, and ices and filling containers would average about 372 gallons per hour, but would vary by container sizes. The total time required for freezing 2,750 gallons of ice cream, sherbets, and ices, and for filling containers the sizes of those assumed herein, is 7 hours and 24 minutes (table 3).

TABLE 3.—*Assumed freezing and filling rate by type of product and container for a peak day of 2,750 gallons of ice cream, sherbets, and ices*

Product and container size	Freezing and filling rate	Containers filled	Total production	Filling time required
	Gallons per hour	*Number*	*Gallons*	*Hours*
Ice cream:				
2½-gallon containers	460	238	595	1.29
Half-gallon cartons	350	3,068	1,534	4.38
Pint cartons	350	2,776	346	.99
Subtotal		6,082	2,475	6.66
Sherbets and ices:				
2½-gallon containers	460	26	65	.14
Half-gallon cartons	350	340	170	.49
Pint cartons	350	320	40	.11
Subtotal		686	275	.74
Total		6,768	2,750	7.40

Suggested Layout of the Plant

The suggested layout of the plant is shown in figure 1. The layout is arranged for efficient product and container flow, space utilization, and equipment arrangement, and for future expansion.

The suggested plant is irregular in shape. Its maximum length is 92 feet 3 inches, and its width at the widest point is 77 feet 6 inches. The layout provides approximately 5,250 square feet of usable floor space.

Components of the Plant

The major components of the plant are (1) receiving and loading area, (2) processing area, (3) freezing area, (4) packaging area, (5) hardening room, (6) 40° F. storage room, (7) dry storage, (8) laboratory, (9) offices, (10) restrooms, (11) boiler and refrigeration room, and (12) cabinet shop.

The components are arranged to provide for short, direct flow of products and containers, and to minimize travel and handling. Space requirements for each component are based on the equipment and working space needed for efficient operation. Size of storage rooms is determined by the number and size of items to be stored, the method of stacking, and the length of storage period. Allowances for aisles are based on the type and amount of traffic handled. The components of the plant are designed and arranged so that expansion will not present a major construction problem.

Pieces of equipment are numbered on the layout and listed in the discussion for easy identification.

Receiving and loading area.—In a small plant it is desirable to combine the receiving and loading-out operations in the same area. This minimizes construction costs and makes possible better use of receiving and load-out workers. The receiving and loading area, which is also used for truck parking, covers a space 22 by 20 feet, or 440 square feet. To the rear is the loading dock, which is 6 feet by 20 feet. The dock is 3 feet above the level of the drive; the height corresponds to that of the bed of the delivery trucks. The width is sufficient for maneuvering the loading carts. Steps at one end lead to the outside. At the other end a door opens off the processing area. Near the center another door, wide enough for handtrucks, leads into the hardening room.

The receiving and loading area is completely sheltered. The drive has a concrete surface sloped one-half inch per foot to the rear to facilitate unloading the milk products, sugar sirup, and corn sirup from tank trucks. A floor drain is located at the rear of the unloading area. There is a wash sink (48) here for hand washing the tank trucks for milk products.[2] The tank trucks for sugar sirup and corn sirup are not washed at the ice cream plant.

The receiving pump (2) for unloading milk products and liquid sugar is located inside the building adjacent to the cream storage vat (4) and is connected through an opening in the wall to the tank truck by a sanitary pipeline, which is removed when not in use and stored on a rack adjacent to the pump. Corn sirup tank trucks are equipped with their own pumps for unloading.

The area will accommodate two tank trucks or two delivery trucks at a time. This is ample space, since all sirup and milk product deliveries are scheduled. Ordinarily, not more than two deliveries of the milk products and one of the liquid sugar and corn sirup are made each week, and they can be made in midday, so that the ice cream delivery trucks are not a problem.

Backed into position at the dock, two trucks can load at one time. There are electrical plug-in connections here for the refrigerating units on the delivery trucks, which are parked here under shelter overnight.

Processing area.—The mix processing, freezing, and packaging areas are combined in one room containing 1,220 square feet of floor space. The mix is processed at one end of this room. The walls of the room are constructed of ceramic tile, and the ceiling is made of moisture-resistant plaster. Acid-resistant tile set in acid-resistant cement is used on the floor. The floor slopes one-fourth inch per foot to drains located at the center of each of the three operations—mix processing, freezing, and packaging. A ceiling height of 14 feet is recommended to provide room for overhead utilities and adequate ventilation.

The control panel (1) contains instruments for checking the weight of receipts and inventory, and controls for assembling mix, pasteurizing, homogenizing, and cooling. Also mounted on this panel are controls for the CIP system for cleaning milk product storage tanks, pasteurizers, and sanitary lines, as well as pushbutton stations for pumps and automatic valves.

Other pieces of equipment in this area are liquid sugar tank, 1,250 gallons (3); corn sirup tank, 500 gallons (29); corn sirup pump, 50 gallons per minute (30), liquid sugar pump, 100 gallons per minute (47); cream storage tank, 600 gallons (4); concentrated skim milk tank,

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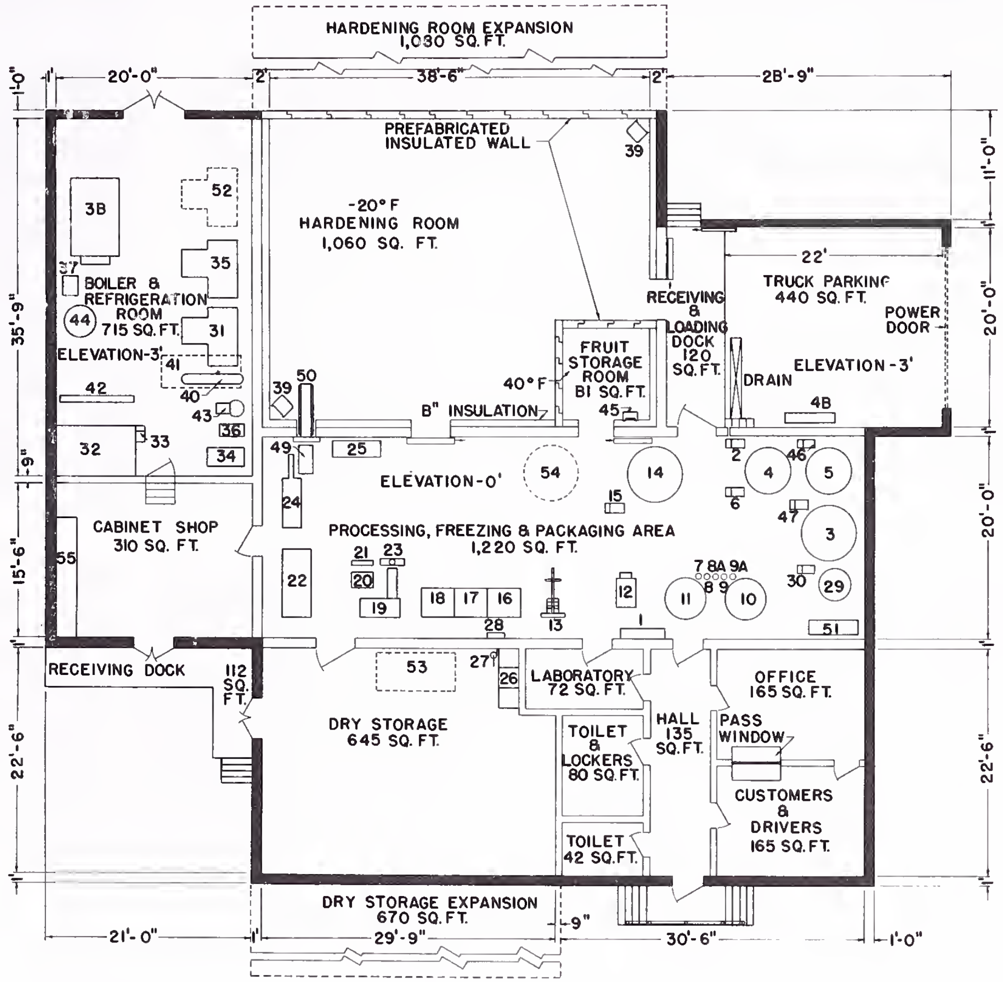
[2] Cleaned-in-place (CIP) washing is not provided because of the small number of trucks to be cleaned. See p. 13 for description of CIP system for cleaning processing equipment.



1 CONTROL PANEL
2 RECEIVING PUMP 100 GPM
3 LIQUID SUGAR TANK 1,250 GAL.
4 CREAM STORAGE TANK 600 GAL.
5 CONC. SKIM MILK STORAGE TANK 600 GAL.
6 CENTRIFUGAL PUMP FOR CREAM 100 GPM
7 AUTOMATIC VALVE FOR LIQUID SUGAR
8 AUTOMATIC VALVE FOR CREAM
8A AUTOMATIC VALVE FOR CONC. SKIM MILK
9 AUTOMATIC VALVE FOR CORN SIRUP
9A AUTOMATIC VALVE FOR WATER
10,11 MIX PASTEURIZER 200 GAL.
12 HOMOGENIZER 400 GPH
13 PLATE COOLER 400 GPH
14 MIX STORAGE TANK 1,600 GAL.
15 PASTEURIZED MIX PUMP 100 GPM
16,17,18 THREE-COMPARTMENT MIX FLAVOR VAT 200 GAL. EACH
19 THREE-TUBE ICE CREAM FREEZER 500 GPH
20 FRUIT FEEDER 12 TO 140 GPH
21 ICE CREAM BLENDER 900 GPH
22 PINT CARTON FILLER 350 GPH
23 2 1/2 GAL. CAN FILLER 500 GPH
24 1/2 GAL. CARTON FILLER 350 GPH
25 6 FT. WASH SINK
26 CIP TANKS 100 GAL. EACH
27 CIP CIRCULATING PUMP 150 GPM
28 CIP CONNECTING STATION
29 CORN SIRUP TANK 500 GAL.
30 CORN SIRUP PUMP 50 GPM
31 40 HP. AMMONIA COMPRESSOR FOR FREEZER
32 ICE BUILDER FOR PLATE COOLER 2,800 LBS.
33 REFRIGERATED WATER PUMP FOR PLATE COOLER 80 GPM
34 5 HP. FREON COMPRESSOR FOR ICE BUILDER
35 30 HP. AMMONIA COMPRESSOR FOR HARDENING ROOM
36 1 1/2 HP. FREON COMPRESSOR FOR TANKS 4, 5 & 14
37 FEED WATER UNIT FOR BOILER
38 STEAM BOILER 50 BHP
39 HARDENING ROOM COOLING UNIT
40 AMMONIA RECEIVER 6 FEET BY 16 INCHES
41 EVAPORATIVE CONDENSER (ON ROOF) 28 TONS
42 ELECTRICAL PANEL
43 1/3 HP. AIR COMPRESSOR
44 HOT WATER TANK 300 GAL.
45 FRUIT STORAGE ROOM COOLING UNIT
46 CENTRIFUGAL PUMP FOR CONC. SKIM 100 GPM
47 LIQUID SUGAR PUMP 100 GPM
48 WASH SINK FOR TANKERS
49 PACKING TABLE
50 BELT CONVEYOR 12 INCHES WIDE
51 6 FT. WASH SINK
52 FUTURE AMMONIA COMPRESSOR
53 AIR CIRCULATING AND HEATING UNIT (ON ROOF)
54 FUTURE MIX STORAGE TANK 1,600 GAL.
55 WORK BENCH

FIGURE 1.—Suggested layout for an automated plant manufacturing 200,000 gallons of ice cream a year.

600 gallons (5); cream pump, 100 gallons per minute (6); concentrated skim milk pump, 100 gallons per minute (46); two 200-gallon mix pasteurizers (10, 11); automatic valves (7, 8, 8a, 9, 9a) for liquid sugar, cream, concentrated skim milk, corn sirup, and water; plate cooler, 400 gallons per hour (13); homogenizer, 400 gallons per hour (12); pasteurized mix storage tank, 1,600 gallons (14); pasteurized mix pump, 100 gallons per minute (15); and CIP connecting station (28). Two 6-foot wash sinks (25, 51) are located one at each end of the freezing-processing area.

All sanitary pipelines in the plant from the raw milk product storage tank to the flavor tanks are 1½ inches in diameter. From the flavor tanks to the freezer the pipes are 1 inch in diameter.

Freezing area.—The equipment involved in freezing the ice cream is as follows: A three-compartment insulated flavor tank, 200 gallons each compartment, (16, 17, 18); a 3-cylinder ammonia-refrigerated freezer, 500 gallons per hour (19); a fruit feeder, 12 to 140 gallons per hour (20); and an ice cream blender, 900 gallons per hour (21).

Packaging area.—The equipment in the packaging area consists of filling machines for pint packages, 350 gallons per hour (22), 2½-gallon cans, 500 gallons per hour (23), and ½-gallon packages, 350 gallons per hour (24), a packing table (49), and a belt conveyor 12 inches wide (50). The pint and half-gallon fillers and the packing table are on rollers so that they can be positioned wherever needed. The table is used for packing 1 gallon of either the half-gallon or pint cartons of ice cream in paper bags, and the belt conveyor for carrying products into the hardening room.

Hardening room.—The hardening room, maintained at a temperature of −20° F., completes the ice cream freezing process. The area of the room is 1,060 square feet. The area needed in a hardening room varies with the proportion of the products in packages and novelties and those in bulk, the number of working days per month, and the number of days of inventory to be carried. This plant manufactures 200,000 gallons of products a year and handles 30,000 gallons of novelties. Of this total, packages are about 80 percent. It is assumed that 10 days' inventory is sufficient. The following is the formula for computing the area of the hardening room:

Annual production × proportion of annual production in peak month ÷ number of working days × day's inventory ÷ gallons stored per square foot[3]

For a plant with the production and packaging assumed for this plant, the area of the hardening room should be—

$$\frac{\frac{230{,}000\times 11}{20}\times 10}{12}=1{,}054 \text{ square feet}$$

The equipment in the room consists of two automatic cooling units, 6.0 tons each (39), and a belt conveyor 12 inches wide (50). The cooling units are in opposite corners of the room; they circulate cold air, which speeds up the hardening process. Temperature is controlled by a room thermostat. Controls for defrosting are manually operated.

The bundles of ice cream enter the hardening room on the belt conveyor (50) in wire cases, which are stacked 10 high on metal racks. Six-foot aisles provide space for load-out carts.

The outer wall of the hardening room is prefabricated. This lends itself better to modification and expansion. The finish of this wall, inside and out, is aluminum, and the insulation is equivalent to 8 inches of fiberglass. The three other walls and the floor are insulated with 8 inches of corkboard. The floor is concrete. The ceiling height is 8½ feet.

40° F. storage room.—The 40° storage room is used for storing fruits, nuts, and flavoring materials. The equipment in this room consists of a 0.2-ton room cooling unit (45), which is operated by the hardening room compressor.

Location of this room adjacent to the hardening room simplifies refrigeration. It is also near the platform where incoming freight is received, and close to the freezing area where the fruits, nuts, and other flavoring materials are used. The insulation of the two outside walls, the ceiling, and the floor is the same as that used in the hardening room. Height of ceiling is 8½ feet. The desired temperature is maintained by thermostatic control. Removable metal shelving is supplied for storing the materials requiring refrigeration. Area of the room is 81 square feet, which is ample for a plant manufacturing 200,000 gallons of ice cream per year, since most of the stock stored here can be replenished in a few days as needed.[4]

The walls adjacent to the hardening room are

[3] Experience in the industry has determined that a plant handling the number of flavors and package sizes assumed for this plant would need 1 square foot of floor space for every 12 gallons of product to be stored.

[4] A common practice is to have a 40° F. storage room equal to 8 to 10 percent of the hardening room area if the storage room is not used for storage of mix or milk products. The exact amount of space needed cannot be determined by formula, since need varies with the distance of the plant from cold storage warehouses and with the reliability and frequency of delivery in the area.

prefabricated to allow for later expansion and are of the same construction as the outer wall of the hardening room.

Dry storage room.[5]—An area of 645 square feet is provided for the storage of paper containers, washing powders, chemical sterilizers, ice cream stabilizers and emulsifiers, cocoa, spare parts for machinery, old office records, new office and plant record forms, and advertising material. The floor is concrete and treated to prevent dusting; walls and ceiling are plastered. The ceiling is 14 feet high. Suitable cabinets and pallets are provided for storage of paper containers. All pallets are 40 inches by 40 inches. The height of the loaded pallets is just under 4 feet. A forklift truck of the walk-behind type is provided for transporting and stacking the palletized cartons on metal racks. The location of this room is convenient to the mix processing and packaging areas, the laboratory, and the office. An outside entrance and dock are provided for handling incoming shipments.

The three 100-gallon solution tanks (26) for the CIP system and the CIP circulating pump (27) are located along the wall next to the laboratory and near the cleaning chemicals.

Laboratory.—The laboratory is across the hall from the manager's office. Acidity, fat, and solids tests are performed here; bacteriological testing is done by an outside laboratory. The plant superintendent, who performs most of the tests, has his office in the laboratory. The area is 72 square feet and has a ceiling height of 8½ feet.

Office.—The office is located at the front of the building. It is divided into two parts—one for drivers, customers, and other business callers, and the other for the plant manager and bookkeeper. Drivers are checked in at the pass window by the bookkeeper. The total area of the office space is 330 square feet. The hallway, 135 square feet, that serves the offices is used also by plant employees. The timeclock is located on the wall of the hallway.

Restrooms.—The two restrooms, serving the office and plant employees, open off the hallway. The men's lavatory and locker room contains 80 square feet, and the women's room contains 42 square feet. Both have 8½ foot ceilings.

Boiler and refrigeration equipment room.—The area of the boiler and refrigeration equipment room is 715 square feet. Its location near the processing, freezing, and hardening areas provides a minimum distance for steam, hot water, and refrigeration lines.

Located in the room are a gas-fired steam boiler, 50 boiler horsepower (38); feed water unit for boiler (37); 5-horsepower compressor for ice builder (34); 12.3-ton compressor for hardening room (35); 1½-horsepower compressor for storage tanks 4, 5, and 14 (36); ice builder (32); sweetwater pump (33); 300-gallon hot water heater tank (44); ammonia compressor for freezer (31); ammonia receiver (40); air compressor (43); electric panel (42); and tools and a workbench for repair work. An evaporative condenser (41) is located on the roof. The total load for the evaporative condenser is 27.1 tons at zero pounds suction pressure. The suggested condenser has a capacity of 28 tons under these operating conditions.

The floor is concrete; walls and ceiling are covered with cement plaster finished with moistureproof paint. The ceiling is 17 feet high. The floor is 3 feet below that of the plant, to facilitate moving equipment in and out and to provide head room for good ventilation. A suction fan at one end near the ceiling provides ventilation. An outside entrance is used for personnel traffic and for moving machinery in and out; the inside entrance opens into the cabinet shop.

Outside the boiler room is the incinerator for disposing of combustible waste material.

Cabinet shop.—The cabinet and repair shop covers 310 square feet. Here are stored new ice cream cabinets and parts for machines used by customers. Repair work on cabinets and minor carpentry and metal work for the plant are done here. A workbench (55) is provided for this purpose. The room has an outside entrance to the receiving dock for moving cabinets in and out. It also has an entrance into the processing area of the plant.

The floor elevation is the same as that of the rest of the plant but 3 feet above that of the boiler room, to which it is connected by stairsteps. Ceiling height is 8½ feet.

Provision for Plant Expansion

The layout for this plant manufacturing 200,000 gallons of ice cream annually can be expanded enough to handle 400,000 gallons. There is no need to increase processing facilities; production can be doubled by increasing the processing days from 8 to 16 per month and hiring more help. However, another 1,600-gallon storage vat (54) will be needed for the pasteurized mix.

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[5] Some plants allow about 3,500 square feet of dry storage area per 1 million gallons of ice cream manufactured. When pallets are used, slightly less space is needed. Since 200,000 gallons are manufactured in this plant, the storage space needed if pallets were not used would be 20 percent of 3,500, or 700 square feet. However, some palletizing is done, and 645 square feet should be ample.

The hardening room facilities should be expanded by 1,080 square feet to handle the 100-percent increase in volume.

The 40° F. storage room is of ample size, since the items stored here can be obtained on very short notice and do not need to be stocked in large amounts. The prefabricated inner walls can be moved easily, to provide more space when the hardening room is expanded.

No additional office, restroom, or laboratory facilities will be needed.

The dry storage room will need to be enlarged. Provision is made for an additional 670 square feet. Since all the materials stored here are readily available from suppliers, large stocks do not need to be carried. The main items to be stored here are the paper containers, which can be palletized for storage and handled with a lift truck. This will make it possible to handle 4 weeks' supply of cartons in a limited space. As the business grows, arrangement can be made for delivery of the cartons each month, or more often if necessary.

Since production can be doubled by merely adding more freezing days to the schedule, the boiler and refrigeration equipment would not require expansion. When the hardening room is expanded, an additional 11.7-ton ammonia compressor (52) should be installed, or the 12.3-ton ammonia compressor (35) exchanged for a larger unit. Also, additional cooling coils would be required in the hardening room.

The evaporative condenser (41) on the roof can handle the present combined ammonia refrigeration loads. When the plant volume is doubled, another evaporative condenser must be added.

Plant Site

The plant site should be of adequate size for the plant proper, for principal driveways to connect the plant with public driveways or city thoroughfares, for customer parking, and for future expansion. The site should be fairly level and well drained. It should have easy access to an ample water supply, electrical power, and sewer facilities.

The layout for a plant at the intersection of two highways on a site 136 feet wide and 170 feet long is shown in figure 2. The plant proper occupies an area approximately 78 feet by 92 feet, near the center of the site.

There is sufficient room for a driveway to come in from one highway, go around the back of the plant and out onto the other highway. The part leading from one highway to the employee parking area is 10 feet wide, and the part leading from the other highway to the docks serving the dry storage room and cabinet shop is 15 feet wide. The receiving and loading area has its own driveway.

Sidewalks lead to the office entrance from both highways.

Several plots facing the highways are suitable for landscaping. The unlandscaped areas around the plant will be surfaced with either concrete or blacktop. The driveways will be concrete able to support the weight of the loaded trucks.

As the layout shows, there is ample space for the planned expansion of the dry storage and hardening rooms without interfering with traffic flow.

How the Plant Operates

The major operations involved in manufacturing ice cream are (1) receiving raw products, (2) assembling mix, (3) pasteurizing, homogenizing, and cooling, (4) freezing, packaging, and storing, (5) loading out products, and (6) cleaning the equipment. Assembling and processing mix and cleaning and sanitizing certain items of equipment are automated operations handled from the control panel (fig. 3). Other operations are mechanized or manually controlled. The flow of mix ingredients and ice cream from receiving through filling is shown in figure 4.

Receiving Raw Products

To save labor, the receiving of raw products follows a definite schedule. The cream and condensed skim milk are received in a two-compartment tank truck on Tuesday and Saturday. The maximum amount of cream received in one day is about 420 gallons during July, the peak production month; the maximum amount of concentrated skim milk is 570 gallons. In the periods of low production, such as January, approximately two-thirds as much milk products will be received.

The two-compartment tank truck containing the milk products backs into the unloading area under the projecting roof. One of the plant workers takes samples of the cream and concentrated skim milk for testing. A sanitary pipeline that extends through the wall connects the tank truck with receiving pump (2) located adjacent to the milk products storage tanks (4, 5). Since the capacity of the unloading pump is 100 gallons per minute, a 1,200-gallon delivery of products can be unloaded in about 12 minutes. About 5 minutes are required to collect the sample, connect the pipeline, and start the pump.

Cream and concentrated skim milk are tested in the laboratory to determine whether the milk

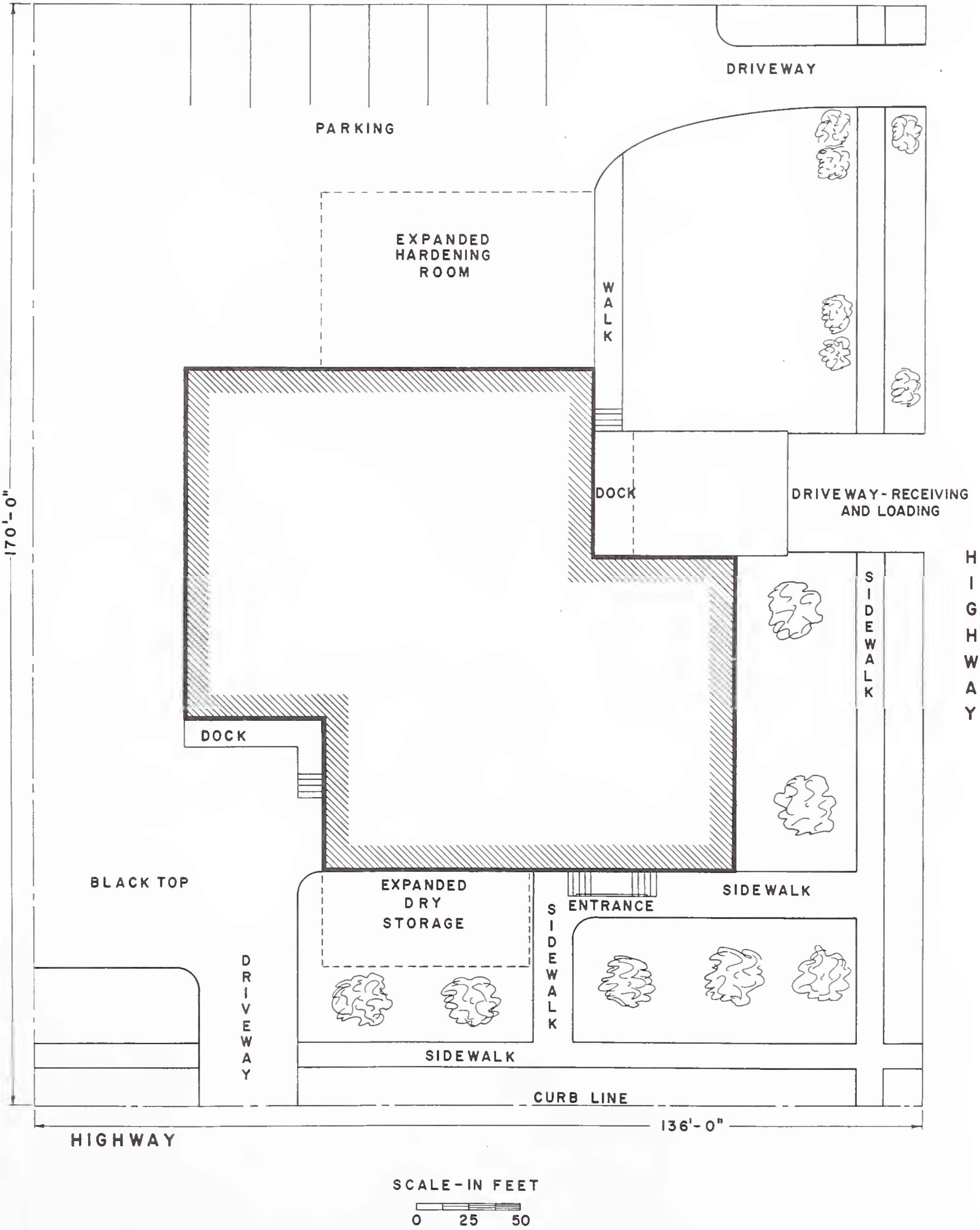


FIGURE 2.—A suggested layout for the site of an automated ice cream plant manufacturing 200,000 gallons of ice cream annually.

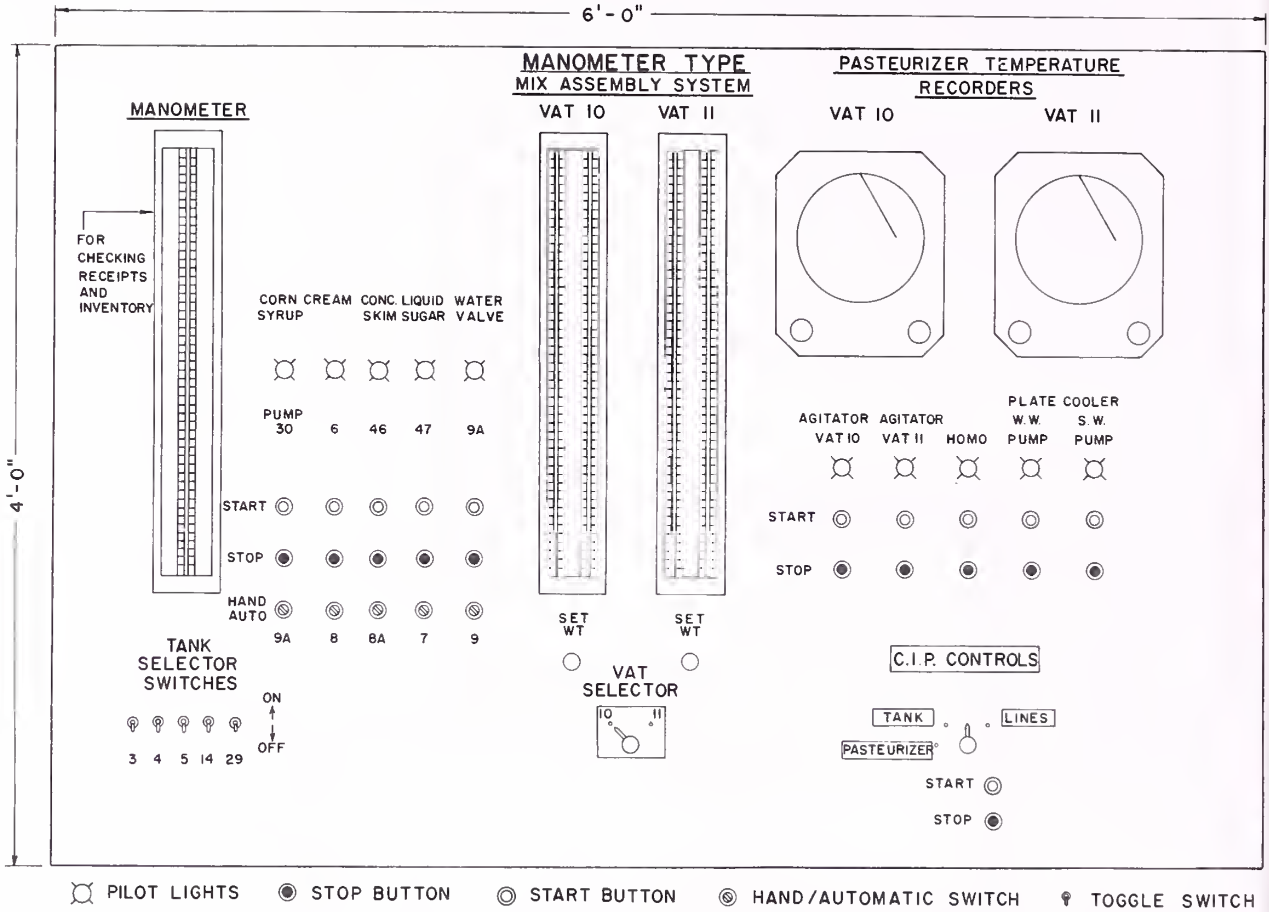


FIGURE 3.—A suggested control panel for an automated ice cream plant manufacturing 200,000 gallons of ice cream annually.

solids are in the proper ratio and concentration. If variation from the standard is significant, a change in the formula will be necessary when the mix is made.

The sweetening agents, liquid sugar and corn sirup, are received in separate tank trucks on Saturday. The amount ordered is determined by reference to the production schedule and mix formulation chart. The trucks unload in the same way as the milk products trucks. The corn sirup truck has its own pump for unloading. Corn sirup is pumped into a 500-gallon tank (29) and the liquid sugar is pumped into a 1,250-gallon tank (3).

At the control panel, the amount of product received or the amount remaining in the tank can be determined by pressing the tank selector switch for the desired storage tank. The manometer, mounted on the left of the control panel, is connected to level transducers located in the bottom of the tanks. A calibration chart serves as a ready reference in converting the manometer reading, in inches, to pounds or gallons.

Novelties are received every Saturday during the peak summer season and about once each 3 to 4 weeks in the winter.

Mix Assembly

The maximum amount of ice cream mix and sherbet and ice mix to be prepared in one month (July) is 12,160 gallons. Assuming that this load is distributed evenly over the 8 mix-making days (Monday and Thursday of each week) in the month, the average amount to be made in 1 day is 1,520 gallons (1,337 gallons of ice cream mix and 183 gallons of sherbet and ice mix). The ingredients are mixed in the two pasteurizing vats (10, 11), each of which holds 200 gallons.

The mix assembly system on the control panel consists of two manometers, labeled "vat 10" and "vat 11", two "set weight" knobs mounted directly below the manometers, a vat selector switch, and to the left of the manometers, pushbuttons (start and stop) and pilot lights for the

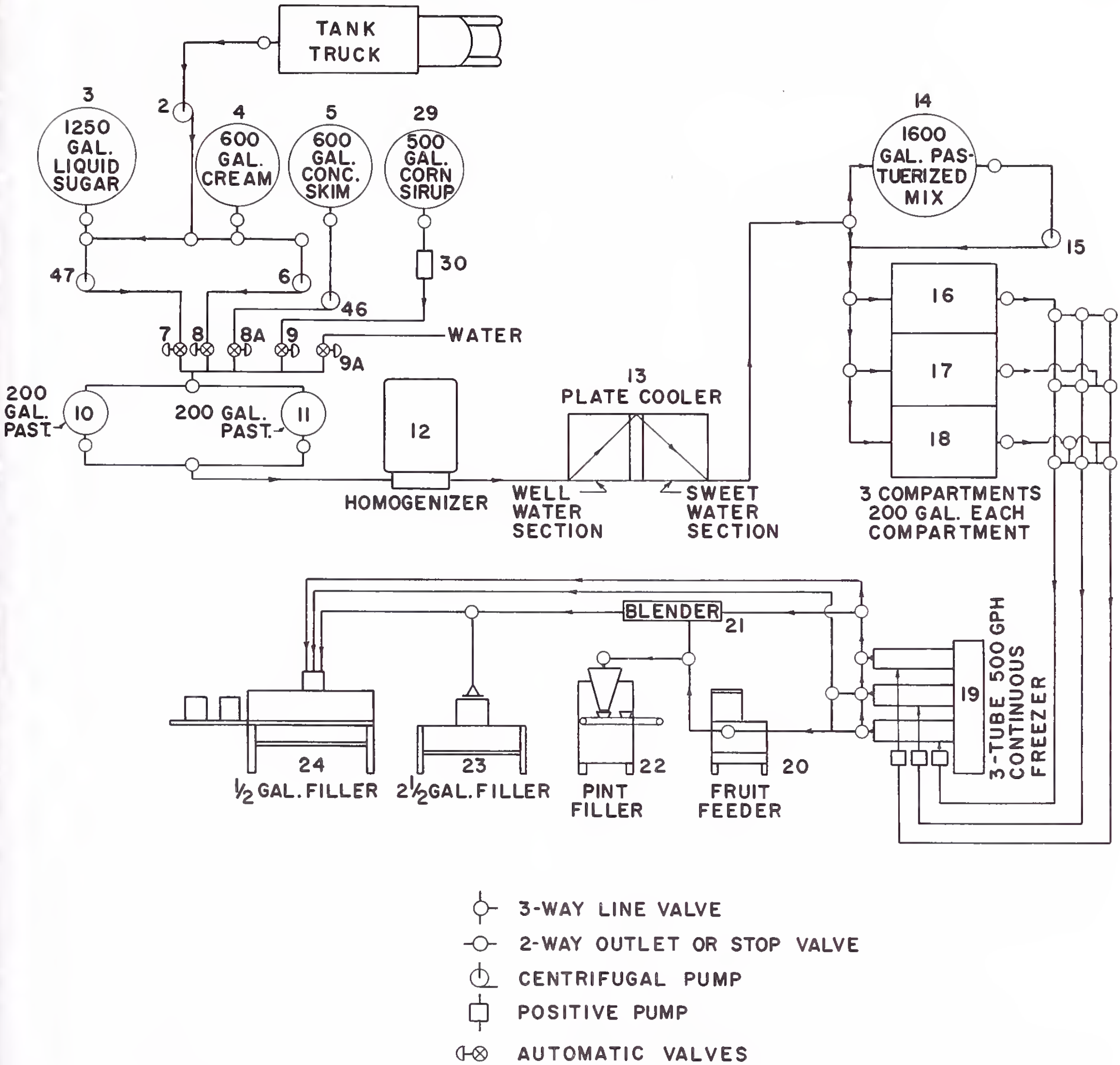


FIGURE 4.—Flow of mix ingredients and ice cream from receiving through filling.

pumps (30, 6, 46, 47, and 9a) and automatic valves (9a, 8, 8a, 7, and 9).

Before mix assembly, the lines are flushed with a sanitizing solution. (See description of CIP system in the section on Cleaning Equipment.)

In assembling a batch of ice cream mix in pasteurizing vat 10, the operator throws the vat selector switch to vat 10, sets the weight of the cream (first ingredient) on the right-hand scale of the manometer, and pushes the start buttons for the cream pump (6) and cream tank valve (8). The pilot light comes on; cream is pumped into the vat until the manometer trips the switch, indicating that the desired weight has been reached; this deactivates the cream pump and shuts off the tank valve automatically. Then the operator sets the weight of the next ingredient (concentrated skim milk) plus the weight of the cream on the manometer and pushes the start buttons for the concentrated skim milk pump (46) and valve (8a). Again, the manometer indicates when the desired weight has been reached, deactivates the skim milk pump, and shuts off the tank valve automatically. He follows the same procedure to add liquid sugar, corn sirup, and water to the mix. The stabilizer and emulsifier (preweighed and bagged) are

added manually to the vat. The total weight of the mix can be read on the right-hand scale of the manometer as a check on the formulation of the batch.

Water ice, which is made from a mixture of sugar sirup, corn sirup, stabilizer, and water, is assembled in vat 10 or 11 in the same manner as ice cream mix. Sherbet, which is made of the same ingredients as water ice, except that about 10 percent ice cream mix is added, is also assembled in the same manner. The desired amount of ice cream mix is pumped from the mix storage vat (14). Citric acid is added just before freezing.

Pasteurizing, Homogenizing, and Cooling

The mix is now ready to be pasteurized. Immediately below the recording thermometers, which are in the upper right-hand corner of the panel board, are pushbuttons for controlling the agitators on the pasteurizing vats (10, 11). Pushbuttons for starting and stopping the homogenizer (12) and the well-water and sweetwater pumps for the plate cooler (13) are also in this section. The operator pushes the button for starting the agitator in either vat 10 or 11; he then manually opens the steam valve to heat the mix to 160° F. The steam is automatically controlled by a self-acting regulator. When the predetermined temperature (160° F.) is reached in the mix, the steam valve closes. The desired temperature is then automatically maintained during the 30-minute holding period. The bulb of the recorder, located in the jacket of the vat, indicates on the recorder the temperature of the mix and the time it has been held. After the 30-minute holding period, the operator opens the pasteurizer valve, pushes the homogenizer start button, and regulates the homogenizer valves to the desired pressure—ordinarily 2,000 pounds on the first valve and 500 pounds on the second, when a two-stage homogenizer is used. The purpose of the second stage valve is to break up the clumps of fat, which are produced in the mix by the first stage, and thereby prevent excessive mix viscosity.

At the same time the homogenizer is being started, the operator pushes the buttons to start the well water and refrigerated sweetwater circulating through the plate cooler (13). Homogenization adds about 5 degrees of frictional heat to the mix. If the mix has been pasteurized at 160° F., it then enters the well-water section of the plate cooler at 165° F. The mix is cooled in this section to approximately 70° F., assuming the well water is 65° F. The mix then passes through the second section of the plate cooler, where the temperature is reduced to 40° F. by the 34° F. sweetwater.

After the mix pasteurizing vat (10) has been emptied and the discharge valve closed, the operator pushes the stop buttons on the homogenizer, vat agitator, well-water pump, and sweetwater pump. The pasteurized mix is now homogenized and ready for storage in the pasteurized mix tank (14), where it is maintained at 40° F.

Mix must be flavored before it enters the freezer. It is first pumped from the pasteurized mix storage vat (14) by the mix pump (15) into one of the three compartments of the flavoring vat (16, 17, 18), and the flavor is added manually. The valves at the three-compartment flavoring vat are so arranged that the mix from any compartment can be fed to any one of the three positive mix pumps on the freezer (19). A second pump, revolving faster than the mix pump (15), not only handles mix from the first pump but sucks air into the system.

The freezer lowers the mix temperature from about 40° F. to about 21°; at the same time air is pumped into the freezing chamber to obtain the desired overrun. The speed of the air pump determines the amount of air incorporated into the mix in the freezer.

The piping and valves beyond the freezer are so arranged that the output of any freezing tube can be sent to any one of the three filling devices either through or around the first feeder (20) or blender (21).

Freezing, Packaging, and Storing

As indicated on the operating schedule (table 1) freezing days will be Tuesday and Friday. The amount of ice cream, sherbet, and ices frozen each of the 8 freezing days in the peak month (July) is approximately 2,750 gallons. The three-cylinder freezer (19) has a rated capacity of 500 gallons per hour at 100 percent overrun. With lower overrun the capacity is less. Bulk ice cream is usually drawn at 90 to 100 percent overrun and package ice cream at 80 to 85 percent overrun. In this report, 85 percent overrun is assumed for all ice cream. Sherbets and ices are normally drawn at about 50 percent overrun.

Freezing the amounts of ice cream, sherbets, and ices needed on a peak day requires approximately 7½ hours operating time. It is therefore advisable that certain duties preparatory to freezing be performed on the mix processing days. These duties include withdrawal of empty containers from storage, makeup of bulk containers, and preparation of fruits, nuts, and flavorings. In this way only the operation of the freezer, the handling of the filled packages at the filling machines, and the transfer of packages into the hardening room need be attended to on freezing days.

The fruit feeder is provided with a 12-to-1

variation in capacity by a combination of a 2-speed motor and a 3-to-1 variable drive, and by halving the piston displacement. The liquid capacity of the fruit feeder varies from 12 to 140 gallons per hour. Large pieces of fruit or whole cherries reduce the top capacity to 90 gallons per hour. For fruit ice cream, the amount of fruit added is 10 to 15 percent of the weight of the mix. When the same fruit ice cream is made in all three cylinders of the freezer at one time, the ice cream from one cylinder is passed through the fruit feeder, where sufficient fruit is added for the total capacity of the freezer. The discharges from the two other cylinders and the fruit feeder are then uniformly mixed in the blender (21).

Valves in the discharge line from the freezer, fruit feeder, or blender regulate the flow of the ice cream into the filling machines. There are two package fillers, one for pints (22) and one for half-gallons (24), and one filler for bulk ice cream in 2½-gallon cans (23). The pint filler is completely automatic; it forms, fills, and closes about 2,800 pint packages per hour (350 gallons per hour). One operator is needed to keep the carton hopper supplied with folded cartons. The half-gallon filler also has a capacity of 350 gallons per hour. It requires one person to set up cartons and one to close the cartons after they have been filled. Both filler speeds are automatically synchronized to the speed at which the ice cream is discharged from the freezer, fruit feeder, or blender.

The operator of the 2½-gallon can filler (23) must set up the paper cans and also place the lids on the filled cans. This filling operation proceeds at about 500 gallons per hour.

The half-gallon and pint packages are placed in paper sacks, making 1-gallon bundles labeled with flavor and size of package. Bagging and labeling aid in storing the ice cream in the hardening room, in taking inventory, and in making delivery. About half of one worker's time is required to place the packages in gallon bags and place the bags in wire cases. Both half-gallons and pints leave the package fillers on a chute, on which several gallons can accumulate. The 1-gallon bags are placed over the end of the chute, and the worker pushes two half-gallon or eight pint packages into a bag, tapes it shut, and places it in the wire case. While a few gallons are accumulating, he has time to attend to other phases of the operation.

The wire cases hold six 1-gallon packages; they are of lightweight construction and can be stacked 10 high in the hardening room. The open construction of the cases permits free air circulation around the ice cream and produces faster hardening.

After being placed in the wire cases, the bundles of ice cream are moved by belt conveyor into the hardening room where a worker stacks them on the floor, keeping different flavors and sizes separate.

Loading Out

Since ice cream deliveries are usually made in the morning, the trucks are loaded the previous afternoon. Loading can be done by one plant worker and the truck driver. Using the driver's load sheet, the plant worker in the hardening room places the items called for onto the loading cart and pushes it out to the loading dock. The truck driver checks the items against his copy of the load sheet and places them in the truck.

Two wholesale delivery trucks are suggested for this plant. Each has a capacity of about 1,200 gallons. Daily deliveries vary with the season, averaging about 800 gallons.

On his return to the plant, the driver checks in at the office, accounts for his sales for the day, and prepares his load sheet for the next day. After reloading, he parks his truck in the enclosed truck parking area and plugs in the truck compressor at the electrical connection.

Cleaning the Equipment

All plant equipment that comes in contact with ice cream or ice cream ingredients must be cleaned immediately after use. A sanitizing solution is run through the system before startup. The pasteurizing vats (10, 11), cream and concentrated skim milk storage tanks (4, 5), pasteurizing mix storage vat (14), and connecting pipelines and automatic valves are cleaned by the CIP system immediately after use. All other equipment is cleaned manually.

There are three essential parts to the CIP system: The solution tanks (26) and circulating pump (27), located in the dry storage room where chemicals are kept; the connecting station (28), located in the processing room on the other side of the wall from the solution tanks; and the controls on the control panel (1) in the processing area, for operating the system. One of the tanks is used for acid solution, one for alkaline solution, and one for the sanitizing solution (chlorine). Chemicals should be changed each operating day. Connecting station 28 directs the cleaning, rinsing, and sanitizing solutions into the circuits desired.

The indicator knob for CIP controls is set for the desired equipment and the automatic control is provided for the various steps in cleaning, rinsing, and sanitizing, which include the following:

1. A complete wash, which consists of an acid and an alkali wash and three rinses.

2. An alkali or acid wash, which consists of a prerinse, the wash, and final rinse.

3. The sanitizing cycle, which is only a water rinse to which a sanitizer such as chlorine is added.

A predetermined time cycle for each cleaning operation is selected at the controls on the solution tanks. Once set, the time period will be selected each time the master switch is turned to the desired operation. The time setting, however, can be varied by a simple adjustment of the controls.

A horn sounds when a cleaning cycle has been completed.

The following is an example of the CIP system showing the various steps in cleaning and sanitizing a pasteurizing vat:

1. Prerinse, 75 seconds
2. Drain vat
3. Delay, 30 seconds
4. Wash (acid) at 145° F., 20 minutes
5. Drain vat
6. Delay, 30 seconds
7. Rinse, 75 seconds
8. Drain vat
9. Delay, 30 seconds
10. Wash (alkaline) at 145° F., 20 minutes
11. Drain vat
12. Delay, 30 seconds
13. Rinse, 75 seconds
14. Drain vat
15. Sanitize with chemical sterilizer (200 parts per million), 10 minutes
16. Drain vat, leaving lines open
17. Stop cycle

Since acid cleaning is needed only on heated surfaces, such as pasteurizers, the controller omits this cycle on such equipment as raw milk storage vats and the pasteurized mix storage tank.

Both the temperature and the time of circulation of any solution can be changed quickly by adjusting the rheostat controlling these operations. This is located on the back of the panel board.

During the circulation of each solution, a pulsator wired into the CIP circuit closes the automatic outlet valve on the tank every 45 seconds and holds it closed for 15 seconds. This cleans the seals and stems of the valve. In pipeline cleaning, the circuits are arranged in such a way that the solution path is alternated through all parts of a three-way valve to provide stem cleaning and sanitizing. If a second circuit cannot be used with an automatic valve, a pulsator opens and closes the valve a sufficient number of times to clean the stem and seals.

All vats and tanks are provided with spray balls or devices to distribute the cleaning, rinsing, and sanitizing solutions under pressure to all surfaces to be treated.

The homogenizer, fruit feeder, freezer, fillers, pumps, and packaging machines are washed manually. Warm (120° F.) water containing 4 ounces of washing powder per 10 gallons of water is first pumped through the equipment for rinsing. The machines are then disassembled and washed and rinsed in wash sink 25 or 51.

It is also customary to wash the milk products truck tanks. Since there will be only two of these truck tanks to be cleaned each week during the peak season, CIP cleaning is not economical. Washing, therefore, is done by hand. Hot and cold water facilities and hose connections are provided in the unloading area for this purpose (48).

Labor Requirements

In this plant during the peak month two full-time plant men plus the foreman and one half-time worker can handle all operations. Running this plant without automation would require three full-time men 5 days a week and two full-time men 4 days a week. The extra labor (equivalent to 1.1 full-time men) for operating the nonautomated plant would be required for hand washing the raw cream, concentrated milk, and mix storage tanks, the connecting pipelines and valves, and the flavoring tanks. Extra labor also would be needed for the manual assembling and processing of the mix ingredients and for hand packaging. Two workers would be needed 4 days a week to perform these operations. They would not work on Saturday.

Assuming that during July three workers in the automated plant worked 20 days of 8 hours each and the fourth worked half time, they would work 560 hours ($3.5 \times 8 \times 20$) to produce 22,000 gallons of ice cream.[6] Productivity per man-hour would then equal 39.3 gallons. However, on a yearly basis the figure would be much less, since efficiency decreases during low production months.

Yearly productivity for the three full-time workers and one half-time worker is figured as follows:

Total hours worked = 7,280 (52 weeks $\times$ 5 days per week $\times$ 8 hours per day $\times$ 3.5 workers)
Gallons per hour = 27.5 (200,000 gallons $\div$ 7,280 man-hours)

For the nonautomated plant, using three full-time workers plus two additional workers 4 days a week (the equivalent of 1.6 full-time workers), the productivity during July would be 30 gallons per hour, and for the year it would be 21 gallons per hour. These figures show the importance of sustaining production at a high level throughout the year to maintain productivity of labor.

The operating schedule shows on what days

[6] These calculations disregard the time necessary to receive and store novelties.

the various plant operations are performed. For example, on Monday mix is made, requiring approximately 6½ hours; the rest of the time is spent in maintenance, receiving materials for dry storage, preparing packages for the next day's freezing, loading out, plant cleaning, and laboratory work. On Tuesday all operations except mix making are performed. Wednesday the plant is closed. Thursday is a repeat of Monday. Friday is a repeat of Tuesday except that no milk products are received. Saturday is spent in cleaning and maintenance work, laboratory testing, receiving mix ingredients, and loading out. Sunday, the plant is closed. Records are kept by the foreman throughout the week.

The work schedule on mix-making days (Monday and Thursday) is as follows:

Worker No. 1:	
8:00–12:00	Sanitizing equipment and making mix.
12:00–12:30	Break for lunch.
12:30– 1:00	Mix making.
1:00– 4:30	Plant cleanup, maintenance.
Worker No. 2 (Foreman):	
8:00–12:30	Sanitizing equipment and making mix.
12:30– 1:00	Break for lunch.
1:00– 4:30	Laboratory, plant records, checking in and loading out trucks.
Worker No. 3:	
8:00–11:30	Receiving items for dry storage; preparing fruits and flavors for ice cream; preparing packages.
11:30–12:00	Break for lunch.
12:00– 1:00	Mix making.
1:00– 4:30	Plant cleanup, maintenance.

The work schedule on freezing days (Tuesday and Friday) is as follows:

A fourth worker (assumed to be half-time) will be added on these 2 days. Worker No. 1 reports for duty at 7:15 a.m. and works until 3:15 p.m. He assembles and sanitizes the freezing and packaging equipment. This requires about ¾ hour. Workers 2, 3, and 4 check in at 8 a.m. The freezing and packaging starts at 8 a.m. and proceeds without stopping until about 3:30 p.m. Thirty-minute breaks for lunch are allowed the four workers between 11:30 a.m. and 1 p.m.

From 3:15 p.m. to 4:15 p.m. worker No. 4 checks in and loads out the delivery trucks. A half-time worker, he generally works more than 8 hours per day on these 2 days.

At the completion of freezing, workers 1 and 3 clean the freezers and packaging equipment. Worker No. 2 (foreman) receives the milk products on Tuesday and works on plant records on Friday. Worker No. 4 cleans the bulk tank trucks that deliver the cream and condensed milk.

It requires about 5 minutes to start and adjust an ice cream freezer; after the freezer is operating, it requires very little attention. A total of about 5 minutes per hour is enough for making minor adjustments necessary to control the weight of the ice cream and the degree it is frozen, and to add flavor to tanks of mix and change tanks feeding the freezer. Each of the three compartments of the mix tank supplies the freezer for nearly 1 hour if a full tank of flavor is required. The foreman handles the freezers.

The remaining 55 minutes of the foreman's time is used in filling packages. With two assistants, he performs the freezing, packaging, and bagging. A fourth worker brings packaging material to the filler, places the bags in wire cases, and stacks the cases in the hardening room. The four-man team is flexible, and each man can, for a short time, do any job or substitute for any other man during breaks.

The work schedule on Saturday involves receiving milk products, liquid sugar and corn sirup, novelties, fruits, and flavors; cleaning milk products trucks; checking in and loading out delivery trucks; and maintenance. One worker checks in at 7 a.m. and two workers at 8 a.m. Their schedule is as follows:

Worker No 1:	
7:00– 9:30	Receiving, weighing, and sampling cream and condensed milk; washing and sanitizing tank trucks.
9:30–10:30	Weighing and receiving liquid sugar and corn sirup.
10:30–11:45	Receiving, recording and storing novelties.
11:45–12:15	Break for lunch.
12:15– 3:30	Cleaning windows and walls in plant.
Worker No. 2 (Foreman):	
8:00–12:00	Laboratory tests, hardening room and dry storage inventory, plant records.
12:00–12:30	Break for lunch.
12:30– 4:30	Maintenance.
Worker No. 3:	
8:00–10:30	Assisting No. 1 in washing and sanitizing tank trucks, and weighing and receiving liquid sugar and corn sirup.
10:30–11:45	Receiving, recording, and storing novelties.
11:45–12:15	Break for lunch.
12:15– 3:00	Cleaning platform and premises outside of building.
3:00– 4:30	Checking in and loading out trucks.

Costs and Possible Benefits of Labor-Saving Devices

The equipment necessary for the automated plant to minimize labor requirements consists of a control panel (1), manometer mix assembly system, CIP system (26, 27, 28), and automatically operated sanitary product valves (7, 8, 8a, 9, 9a). Estimated cost of this equipment is $25,000 more than that for a nonautomated plant.

It is estimated that the automated ice cream plant handling 200,000 gallons annually could operate with one less full-time worker and one less half-time worker than an efficient nonautomated ice cream plant handling the same volume.

Based on an assumed cost of $6,500 annually per worker (salary plus fringe benefits), annual savings in labor would amount to $9,750 for an automated plant. If 20 percent is allowed annually for ownership and operating costs (depreciation, maintenance, insurance, taxes, and interest), costs would amount to $5,000, and annual saving to $4,750.

Production per man-hour of labor should be higher in the automated plant than in the nonautomated plant. Based on the estimates in the section on "Labor Requirements," the production per man-hour is roughly 30 percent greater for an automated plant than for a nonautomated plant.

Machine-controlled operations should reduce in-plant product losses. They also should provide for more uniform quality than is obtained in a nonautomated plant using conventional equipment. No data are available for the savings that would be realized from these two items.

PLANT MANUFACTURING 1 MILLION GALLONS OF ICE CREAM AND 250,000 GALLONS OF NOVELTIES A YEAR

Assumptions With Respect to Plant Operations

To illustrate principles of plant layout and methods of operation for a large-scale automated ice cream plant, we made the following assumptions:

The same composition of mix ingredients is used as in the smaller plant (see table 2). The same 12 flavors of ice cream, ices, and sherbets are produced.

Production consists of 900,000 gallons of ice cream (72 percent of the total), 100,000 gallons of ices and sherbets (8 percent), and 250,000 gallons of novelties (20 percent).

Of the 1 million gallons of ice cream produced, 24 percent would be packaged in 2½-gallon cans, 62 percent in half-gallon cartons, and 14 percent in pint cartons.

Because of the variety of flavors and products carried in inventory, production is planned on a monthly and weekly basis. Some flavors are made only once in 2 or 3 weeks; no single flavor sells in such quantity that it must be made every freezing day.

To reduce production needs during the peak months, manufacturers start to build an inventory in the early spring. Usually, they have about a 10-day inventory by the peak season. This inventory provides for sudden large increases in demand. The larger the territory served, the more necessary it is for the plant to be prepared for unexpected increases.

Table 4 shows the assumed sales, production, and end-of-month inventory for a plant the size of this one.

During July, the peak sales month, 135,000 gallons of products are made from 77,000 gallons of mix in 20 operating days. This is an average of 6,750 gallons per day from 3,850 gallons of mix, or about thirteen 300-gallon batches.

Twenty operating days are scheduled in June, July, and August. The number of days scheduled as operating days diminishes each month to a low of 11 days for 75,000 gallons in December. To maintain the highest level of efficiency, the plant is scheduled to produce approximately the same amount of product each operating day.

The plant operates 5 days each week. No products are manufactured on Wednesday and Sunday.

Suggested Layout of the Plant

The layout (fig. 5) shows the arrangement of the components of the plant. In organizing these components into an efficient unit, consideration was given to product and container flow, floor space utilization, labor utilization, centralized supervision, and future expansion.

TABLE 4.—*Assumed sales, production, and inventory in a plant handling 1 million gallons of ice cream and 250,000 gallons of novelties, by month*

Month	Production	Sales	Inventory at end of month[1]
	Gallons	*Gallons*	*Gallons*
December			30,000
January	80,000	76,250	33,750
February	80,000	80,000	33,750
March	100,000	95,000	38,750
April	110,000	102,500	46,250
May	120,000	115,000	51,250
June	135,000	132,500	53,750
July	135,000	141,250	47,500
August	135,000	133,750	48,750
September	110,000	116,250	42,500
October	90,000	95,000	37,500
November	80,000	80,000	37,500
December	75,000	82,500	30,000
Total	1,250,000	1,250,000	

[1] Does not include truck inventory of about 10,000 gallons.

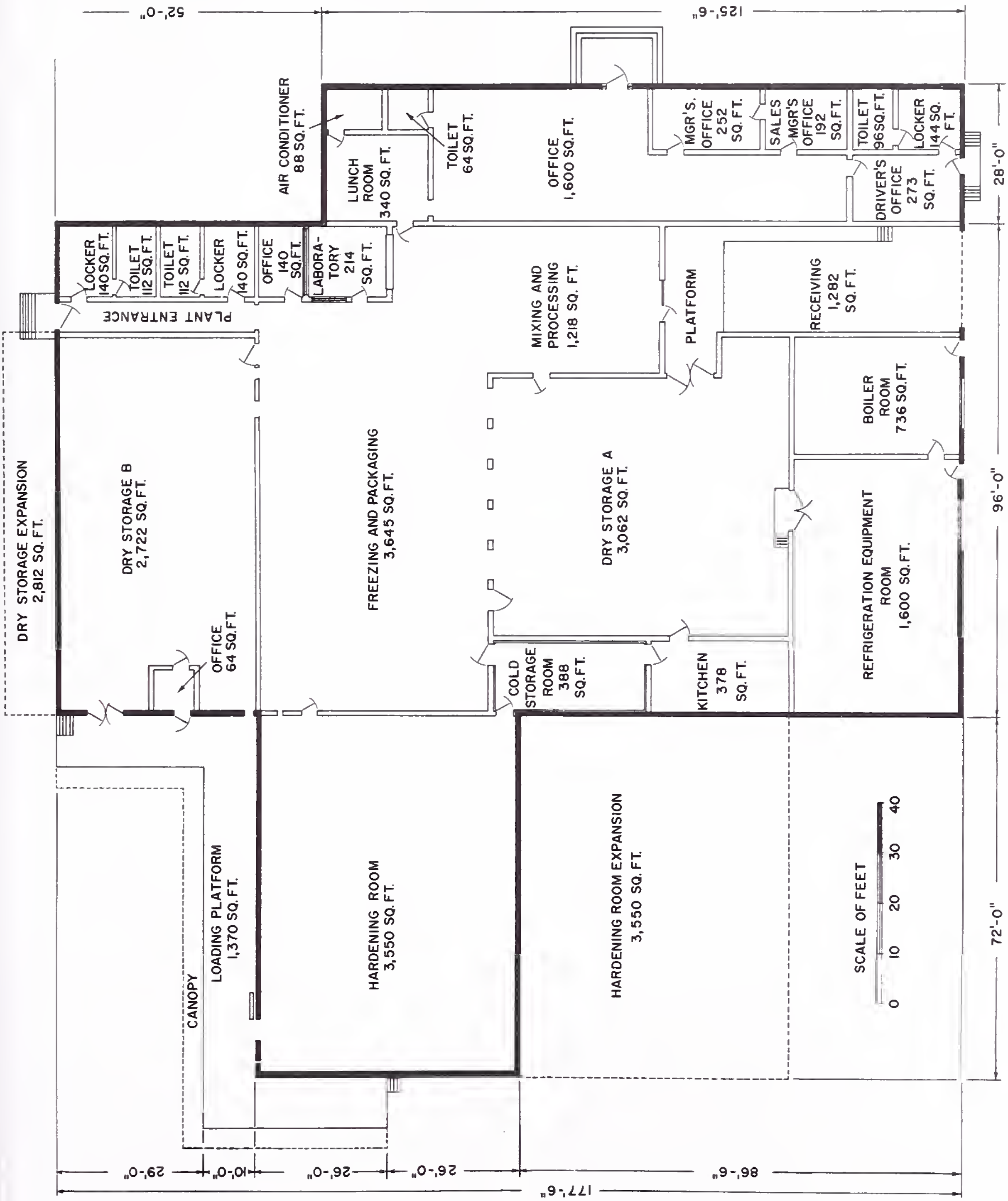


FIGURE 5.—Suggested layout for an automated plant manufacturing 1 million gallons of ice cream and 250,000 gallons of novelties annually.

In no case does the product flow line cross itself. The raw ingredients come into the plant at one end and leave as finished products at the other.

The suggested plant is irregular in shape. Maximum length is 196 feet, and maximum width, 177.5 feet. The layout provides approximately 22,494 square feet of usable floor space.

Components of the Plant

The main components of the plant are receiving area, mixing and processing area, freezing and packaging area, hardening room, cold storage room and kitchen, dry storage rooms, laboratory, offices and locker rooms, loading out area, boiler room, and refrigeration equipment room. A garage and cabinet shop are also on the plant site.

The layout of the receiving area, mix assembly and processing area, freezing and packaging area, storage areas (except dry storage B), and boiler and refrigeration equipment rooms shows the location of the major items of equipment suggested (fig. 6). Each item of equipment is numbered in the layout to make it easier for the reader to follow the processing procedure.

Receiving area.—The receiving area, including platforms, contains 1,282 square feet. One platform is 3 feet wide and 3 feet high and extends 30 feet along one side of the area with steps at one end. This platform serves as a walkway between the main receiving dock and the drivers' office. Connecting with this platform in the rear is another platform of the same height but 12 feet wide. This platform is wide enough for the opening of the doors of large trailer trucks bringing supplies and freight items for unloading at the dock and for the maneuvering of forklift trucks. The height of the dock is the same as that of the floor of the trailer trucks. The rear platform has doorways leading into the mix assembly and processing area and dry storage area A. The two doorways are wide enough for moving large pieces of equipment in and out.

A shelter extends over the entire receiving area. The floor is pitched ½ inch per foot toward the rear platform to a floor drain 16 feet long and covered with a cast iron grating. The pitched floor facilitates the unloading of the tankers, which back in to unload. Other freight items, such as stabilizers, flavorings, and washing powders, are also delivered here. The area can be closed to the outside by an overhead, power-operated door. At the rear of the receiving shelter beneath the platform is the 150-gallon-per-minute receiving pump (3) for unloading milk and cream from tank trucks. Other pieces of equipment in the receiving area are the CIP transport washer on hoist (12) and a portable CIP return pump (85a).

Mixing and processing area.—The mixing and processing area covers 1,218 square feet. Walls in this area are constructed of ceramic tile, and the 14-foot ceiling is made of moisture-resistant material. The tile floor slopes ¼ inch per foot, to drains near each end of the room. Here is housed the following equipment: Master control panel (1); raw cream storage tank (4); concentrated skim milk storage tank (5); mix assembly tanks (8, 9); plate pasteurizer (24); ultrahigh-temperature system (UHT) consisting of steam infuser (20), holding tube (19), vacuum deaerator (28), and vacuum deaerator discharge pump (28a); infeed balance tank (23); homogenizer (26); centrifugal pumps (35a, b, c, and d); CIP connecting station (2a); load cells (79); flow diversion valve (21); positive displacement timing pump (22); water heater (25); hot water pump (75); and portable cleanup tank (87).

The control panel (1) is located in the mixing and processing area against the laboratory wall. It is at a point where the processes controlled by the panel can be conveniently observed by the operator. (A diagram of the control panel and a description of the way it works are given in the section "How the Plant Operates.")

Two vertical 1,500-gallon storage tanks are used—one for raw cream (4) and one for concentrated skim milk (5). They are insulated, and each has 80 square feet of cold wall (ammonia) surface. They are located near the receiving area and require short sanitary pipelines for receiving the milk products. The tanks have load cells (79) built into the legs, for weighing the contents of the tank, and are equipped with built-in spray balls for CIP cleaning and sterilizing.

Two 300-gallon mix assembly tanks (8, 9) are located across the room from the raw cream and concentrated skim milk tanks. This location permits the use of short sanitary pipelines for connecting the tanks with the cream and skim milk tanks, liquid sugar and corn sirup tanks in dry storage room A, and the processing equipment. The assembly tanks are equipped with load cells for automatic mix assembly and an agitator to keep the mix uniformly blended as it is pumped from the tanks.

Because of the large volume of mix to be processed, a continuous-flow system is preferred. Therefore, a 600-gallons-per-hour, plate-type pasteurizer (24) was selected for this plant. Since this pasteurizer employs regenerative principles of heating and cooling, there is considerable saving in heat energy. The capacity can be increased by simply adding more plates. This system is entirely closed and lends itself to automatic processing and cleaning.

With the steam infuser heater (20) and a vacuum cylinder or deaerator (28), the mix can be heated rapidly to temperatures above 212° F. after it leaves the plate pasteurizer and then cooled rapidly to temperatures below 212° F. and deaerated at the same time. This results in a product with an improved flavor, better resistance to fat oxidation, and a smoother texture.

A holding tube (19) holds the mix at 230° F. for 30 seconds.

Freezing and packaging area.—Freezing and packaging operations are carried on in a 3,645-square-foot area.

Three 1,500-gallon mix storage tanks (30, 31, and 32) are located in a row near the plate pasteurizer. The tanks are equipped for direct-expansion cooling and automatic weighing. They are bulkheaded through the wall so that most of the tank exterior is in dry storage room A. This is done for economy, since less frequent exterior cleaning of the tanks will then be needed. A 50-gallon-per-minute centrifugal pump (35e, f, and g) is connected to each mix storage tank.

A three-compartment flavoring tank (36) is used in manufacturing ice cream, sherbet, and ices. Each compartment has a capacity of 250 gallons. Next to the mix flavor tank is a 3-cylinder continuous freezer (38), refrigerated by direct expansion. Each cylinder has a freezing capacity of 300 gallons per hour at 85 percent overrun.

The fruit feeder (41) injects chunks of fruit or nuts into the ice cream as it leaves the freezer. By using the two-speed motor and 3-to-1 variable speed drive with which the feeder is equipped and halving the piston displacement, the liquid capacity of the feeder can be varied from 12 to 144 gallons per hour. Large pieces of fruit or whole cherries reduce the top capacity to 90 gallons per hour.

There are three filling machines. One machine (42) fills 2½-gallon cans at the rate of 900 gallons per hour. The can former (91) shapes the paper cans.

The half-gallon-carton filler (44) has a capacity of 1,000 gallons per hour but would operate at 900 gallons per hour. A conveyor at the end of the machine carries filled cartons to the overwrap machine (46). On the end away from the conveyor is a magazine which holds folded half-gallon cartons. The filler adjusts itself automatically to the output of the freezer. It is equipped with a manifold—a pipe with several outlets—so that one, two, or three flavors may be fed into the package from one, two, or three freezer cylinders to give either a solid or a multilayered and multiflavored ice cream.

The pint-carton filler (45) operates at a maximum speed of 500 gallons per hour, but adjusts its speed to the output of the freezer. It has two empty carton magazines and two filling valves; the cartons are discharged in two lines.

To facilitate handling, both the half-gallon and the pint packages are wrapped with paper in gallon bundles. The overwrap machine (46) adjusts itself automatically to the discharge of the package filling machines; it has a top speed of 2,000 bundles per hour. The bundles move on a conveyor (53) to the package grouper (49). The grouper collects and sends eight bundles to the crater (55), where they are automatically placed in wire baskets that are carried into the hardening room on an overhead continuous conveyor system (56).

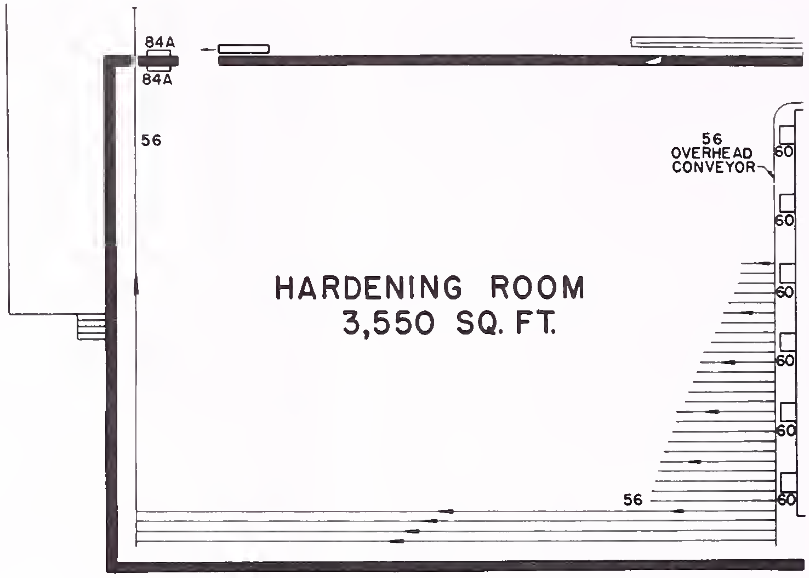
A two-compartment flavoring tank (29) is used in manufacturing novelties. Each compartment holds 125 gallons.

A one-cylinder, 180-gallons-per-hour, continuous freezer (40), refrigerated by ammonia, is required to slush-freeze the ice cream mix and ice mix for bars on sticks and chocolate bars without sticks. These novelties are frozen in molds immersed in a brine tank (50), 27 feet 7 inches by 31 inches, at the rate of 500 dozen per hour; the tank is part of a novelty-making unit.

Ice cream for 4-ounce cups is made in the same freezer as the ice cream for novelties and from there is pumped to the cup filler (capacity 250 cups per minute) and boxer (48), which boxes cups in units of a dozen.

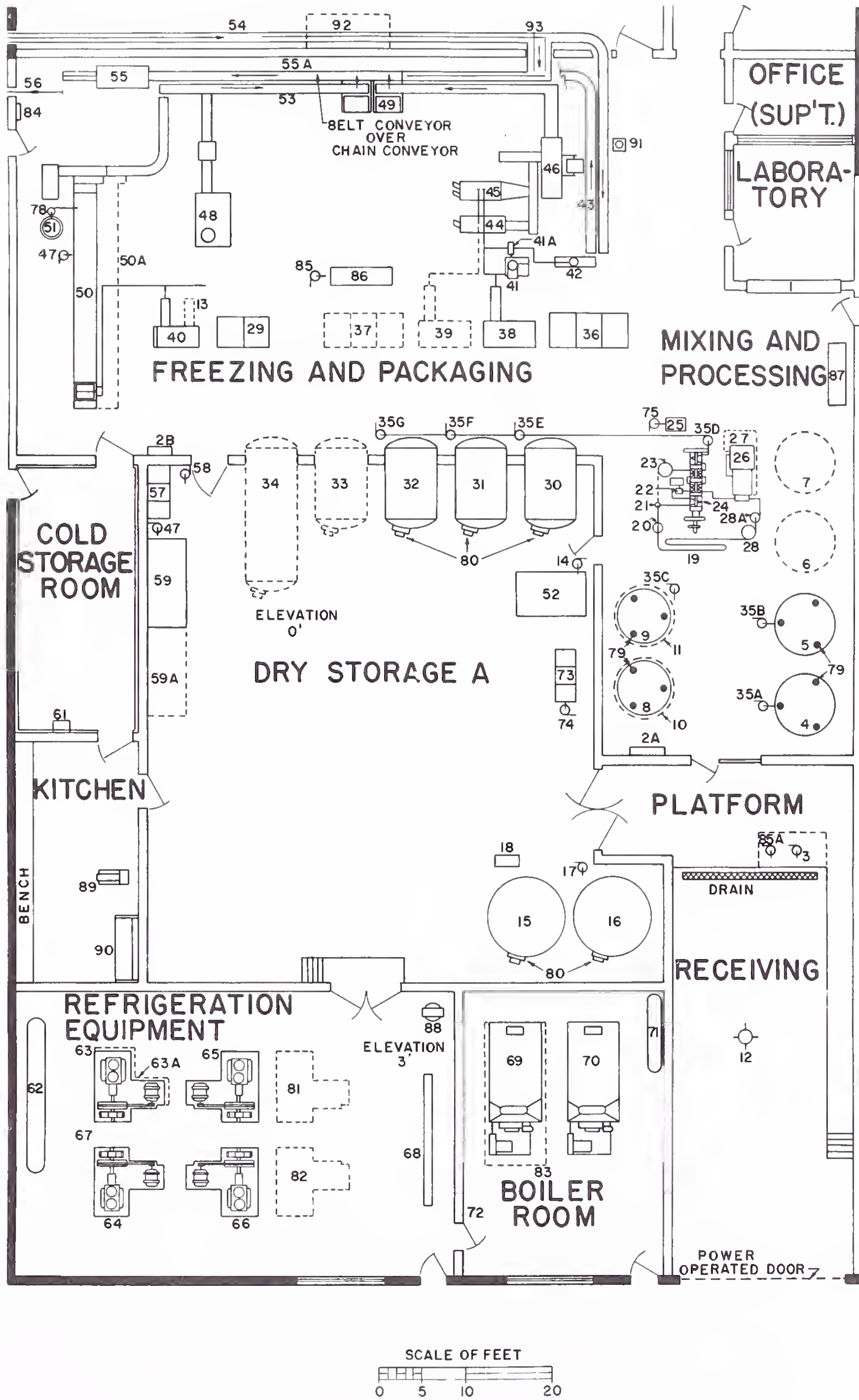
Hardening room.—Equipment in the hardening room consists of overhead conveyor system (56), −20° F. cooling units (60), and conveyor selector switch (84a). The hardening room walls, ceiling, and floor are prefabricated. A number of the newer installations in this country are of this type. The advantages are that materials are readily available in all sections of the country; the room can be easily modified and expanded; walls are durable and well insulated; and the cost is usually lower than that of similar facilities constructed on the job.

The room is built on a foundation leaving at least 2 feet of space for air circulation under the floor. The floor, walls, and ceiling have 8 inches of glass wool or equivalent insulation. The floor is concrete and the wall sections have aluminum sheeting on both sides. These sections come in 4-foot widths and in the height required. The room is divided into an upper area and a lower area by a false ceiling. The ceiling of the lower area is 8 feet high, and the upper area is 4 feet high. The upper area, which extends the length and width of the room, is called the plenum chamber. It provides a blast freezing area for faster hardening of the pints, half-gallons, and cups of ice cream. The hardened ice cream is stored in the area below.



1 CONTROL PANEL
2A, 2B CIP CONNECTING STATIONS
3 RECEIVING PUMP 150 GPM
4 RAW CREAM TANK 1,500 GAL.
5 CONCENTRATED SKIM MILK TANK 1,500 GAL.
6 FUTURE CREAM TANK 1,500 GAL.
7 FUTURE CONCENTRATED SKIM MILK TANK 1,500 GAL.
8 MIX ASSEMBLY TANK 300 GAL.
9 MIX ASSEMBLY TANK 300 GAL.
10, 11 FUTURE MIX ASSEMBLY TANKS 600 GAL. EACH
12 CIP TRANSPORT TANK WASHER ON HOIST
13 FUTURE 1-CYLINDER CONTINUOUS FREEZER 180 GPH
14 CENTRIFUGAL PUMP FOR ICE WATER 100 GPM
15 CORN SIRUP TANK 2,800 GAL.
16 LIOUID SUGAR TANK 2,800 GAL.
17 CENTRIFUGAL PUMP FOR LIOUID SUGAR 50 GPM
18 ROTARY SIRUP PUMP 30 GPM
19 PASTEURIZER 30-SECOND HOLDING TUBE
20 STEAM INFUSER HEATER
21 FLOW DIVERSION VALVE
22 POSITIVE DISPLACEMENT TIMING PUMP 10 TO 20 GPM
23 INFEED BALANCE TANK
24 PLATE PASTEURIZER 600 GPH
25 WATER HEATER FOR PLATE PASTEURIZER
26 HOMOGENIZER 600 GPH
27 FUTURE HOMOGENIZER 1,200 GPH
28 VACUUM DEAERATOR
28A VACUUM DEAERATOR DISCHARGE PUMP
29 MIX FLAVOR TANK WITH TWO 125-GAL. COMPARTMENTS
30–32 MIX STORAGE TANKS 1,500 GAL. EACH
33 FUTURE MIX STORAGE TANK 1,500 GAL.
34 FUTURE MIX STORAGE TANK 3,000 GAL.
35 SANITARY CENTRIFUGAL PUMPS:
A, B, E, F, G—50 GPM
C—25 GPM
D—10 GPM
36 MIX FLAVOR TANK WITH THREE 250-GAL. COMPARTMENTS
37 FUTURE MIX FLAVOR TANK WITH THREE 250-GAL. COMPARTMENTS
38 3-CYLINDER CONTINUOUS FREEZER 900 GPH
39 FUTURE 3-CYLINDER CONTINUOUS FREEZER 900 GPH
40 1-CYLINDER CONTINUOUS FREEZER 180 GPH
41 FRUIT FEEDER 10 TO 120 GPH
41A BLENDER
42 BULK CAN FILLER
43 ASCENDING CONVEYOR FOR BULK CANS IN BASKETS
44 ½-GAL.-CARTON FILLER
45 PINT-CARTON FILLER
46 OVERWRAP MACHINE
47 BRINE CIRCULATING PUMP 250 GPM
48 CUP FILLER AND BOXER
49 PACKAGE GROUPER
50 STICK NOVELTY BRINE TANK SYSTEM
50A FUTURE STICK NOVELTY BRINE TANK SYSTEM
51 CHOCOLATE CIRCULATING UNIT 10 GPM
52 12,000-LB. ICE BUILDER
53 GROUPING CONVEYOR
54 WIRE-BASKET CONVEYOR
55 PACKAGE CRATER
55A CRATER INFEED BELT
56 OVERHEAD CONVEYOR SYSTEM
57 3-TANK CIP UNIT
58 CIP CIRCULATING PUMP 160 GPM
59 SHELL AND TUBE NOVELTY BRINE COOLER
59A FUTURE SHELL AND TUBE NOVELTY BRINE COOLER
60 −20° F. COOLING UNIT, 5.5 TON, WITH FAN AND ELECTRIC DEFROST
61 40° F. COOLING UNIT
62 AMMONIA RECEIVER
63 AMMONIA BOOSTER COMPRESSOR 30 TONS
63A FUTURE AMMONIA BOOSTER COMPRESSOR 60 TONS
64 AMMONIA BOOSTER COMPRESSOR 69 TONS
65 AMMONIA COMPRESSOR 53 TONS
66 AMMONIA COMPRESSOR 75.4 TONS
67 LIOUID AMMONIA INTERCOOLER
68 ELECTRIC PANEL BOARD
69 STEAM BOILER 50 BHP
70 STEAM BOILER 50 BHP
71 HOT WATER TANK
72 BOILER FEED WATER SYSTEM
73 CIP SYSTEM
74 CIP CIRCULATING PUMP 160 GPM
75 HOT WATER CENTRIFUGAL PUMP FOR HTST 100 GPM
76 EVAPORATIVE CONDENSER 130 TONS
77 FUTURE EVAPORATIVE CONDENSER 130 TONS
78 CENTRIFUGAL PUMP FOR CHOCOLATE 10 GPM
79 LOAD CELLS
80 LEVEL TRANSMITTER
81 FUTURE BOOSTER COMPRESSOR 68.85 TONS
82 FUTURE COMPRESSOR 113.70 TONS
B3 FUTURE BOILER 100 BHP
84, 84A CONVEYOR SELECTOR SWITCHES
85, 85A PORTABLE CIP RETURN PUMPS
86, 87 PORTABLE CLEANUP TANKS
88 AIR COMPRESSOR
89 EXPERIMENTAL COUNTER-TYPE ICE CREAM FREEZER
90 ICE CREAM STORAGE CABINET
91 2½-GAL. CAN FORMING MACHINE
92 HEATING AND VENTILATING UNITS MOUNTED ON ROOF
93 AUTOMATIC BASKET DIVIDER

FIGURE 6.—Suggested layout of equipment in the receiving area, mix assembly and processing area, freezing
an automated plant manufacturing 1¼ million



and packaging area, storage areas (except dry storage B), and boiler and refrigeration equipment rooms for gallons of ice cream and novelties annually.

Conveyor system 56 leads from the freezing and packaging area into the plenum chamber. In the chamber, 30 crosslines from the conveyor extend the length of the room; at the end of the room the conveyor leads out onto the loading platform. The hardened product is automatically fed down this conveyor, which is pitched 4 inches per foot, to the lower part of the hardening room at 11½ feet per minute. Here the product is placed either on pallets or on truck-loading racks. Special orders can be sent to the loading dock via the overhead conveyor.

The conveyor system is operated by a selector switch (84) in the freezing and packaging area and a selector switch (84a) on the loading platform. Operation of the system is described in the section "How the Plant Operates."

The six refrigeration units (60) located at one side of the room draw air in from the floor, cool it, and discharge the chilled air at high velocity into the 4-foot plenum chamber. In this way, freshly frozen packages of ice cream and novelties that are moved slowly through the area on the conveyor crosslines are rapidly cooled. Ducts scattered about the false ceiling permit some of the air blast to circulate into the area below the plenum chamber where the hardened ice cream is stored. The air is then returned to the refrigeration units, where it is again chilled and recirculated.

The system of hardening used in this plant eliminates the need for loose stacking the product in the storage area; the hardening room floor space can be used for solid stacking for storage, since the hardening is done in the plenum chamber. Storage capacity is further increased by using the overhead space in the plenum chamber, which will hold 1 day's freezing.

With the assumed composition of flavors and package sizes, this hardening room can store about 20 gallons per square foot of floor space. Ten days' inventory would require 68,750 gallons of product and 3,438 square feet of floor space. The area provided is 3,550 square feet. The small amount of frozen fruit stored in the hardening room is insignificant in calculating space requirements.

Cold storage room and kitchen.—The cold storage room, 388 square feet, is located adjacent to the freezing room and is connected with it by a door to facilitate the moving of flavoring materials to the flavor tanks or fruit blender. This room also connects with the hardening room, where frozen fruit supplies are kept. A door at one end of the room opens into a 378-square-foot kitchen.

For a plant manufacturing a million gallons of ice cream per year, the expense of a kitchen for preparing flavoring materials, such as adding sugar to fresh fruit or roasting nutmeats, is justified. The room is also used for product evaluation. A small ice cream freezer (89), used for making experimental ice cream, and an ice cream storage cabinet (90) are kept here.

The kitchen has tile on the lower part of the walls and a tiled floor with a drain. The upper part of the walls and the ceiling are painted plaster.

The cold storage room is insulated with 4 inches of corkboard in the walls, ceiling, and floor. The height of the ceiling is 8½ feet. A cooling unit (61) located at one end of the room operates from the hardening room compressor and automatically maintains the temperature of 35° F. The floor is concrete, and the walls are plastered. Items to be stored in this room are placed on removable metal shelves. Most flavoring materials are bought on contract for delivery as needed. Consequently, it is not necessary to store more than a few weeks' supply.

Dry storage rooms.—For greater convenience two dry storage rooms are provided: One is for storing the daily supply of such needs as cleaners, sterilizers, and paper containers (room A); the other is for storing the reserve supply of these items, as well as office supplies and records, sales materials, and other items that do not require refrigeration (room B). Both storage rooms are in locations convenient to the mixing and freezing areas and to the office.

The equipment located in dry storage room A consists of CIP units (57 and 73), CIP circulating pumps (58 and 74), brine circulating pump (47), shell and tube novelty brine cooler (59), level transmitters (80), mix storage tanks (30, 31, and 32), centrifugal pumps (14 and 17), ice builder (52), corn sirup tank (15), liquid sugar tank (16), and rotary pump (18). The equipment in dry storage room B consists of a wire-basket conveyor (54), and an automatic basket divider (93).

The reserve storage room (B) has an outside entrance from the loading platform where the incoming paper cartons are loaded onto pallets for storage. This room has a usable floor space of 2,722 square feet. The other dry storage room (A) has 3,062 square feet of usable floor space. It is a common practice to allow 350 square feet of dry storage space for each 100,000 gallons of ice cream made. This plant would therefore require 4,375 square feet. The total net dry storage space for this plant is 5,784 square feet.

The ceilings of the storage rooms are 14 feet high, and metal racks allow stacking pallets three high. A forklift truck of the walk-behind type is used to transport and stack pallets. The walls are painted concrete block and the floor is concrete. Supplies for the storage areas can be

unloaded at either the tanker-receiving platform or the loading platform.

The shipping clerk's office is in the reserve storage room (B) near the loading platform. This makes it possible for him to double as a receiving clerk when dry supplies are unloaded.

Offices, laboratory, and locker area.—Administrative offices are at the front of the building. The general office contains 1,600 square feet. To the left of the main entrance is the manager's office (252 square feet), and immediately back of it is the sales manager's office (192 square feet). An office (273 square feet), a locker room (144 square feet), and a restroom (96 square feet) for the drivers are at the extreme end of this area and adjacent to the sales manager's office. At the opposite end of the office area are the company lunch room (340 square feet—enough for 25 to 30 people), which serves all the employees, a restroom (64 square feet), and the office air-conditioning room (88 square feet). The office is well situated with respect to the street entrance, laboratory, superintendent's office, and the processing area. The ceiling is 8½ feet high.

The laboratory (214 square feet) is adjacent to the processing and freezing areas and the superintendent's office. It contains facilities for testing for fat, total solids, and bacteria. The ceiling is 8½ feet high. The walls and floor are tiled, and the ceiling is plastered.

The superintendent's office (140 square feet) is between the laboratory and the locker room. It is conveniently located for supervision of plant operations.

There are two lavatories and locker rooms for the plant workers—one for men and one for women. Each locker room is 140 square feet in area and each lavatory is 112 square feet. These facilities are conveniently located near the processing and freezing rooms and the plant entrance. The floors and walls are of tile. The ceiling height is 8½ feet.

Loading area.—About 10 wholesale trucks will be required during the summer season, the exact number depending on the area of distribution. The maximum capacity of the wholesale trucks selected is 1,500 gallons each, but the usual load will be about 1,200 gallons. The trucks are loaded at the platform next to the hardening room. There is space for six trucks to load at one time. The Z-shaped platform extends from the middle of the end of the hardening room across the side of this room and across the end of dry storage room B, an overall length of 137 feet. It is 10 feet wide. This width of platform permits moving the 200-gallon racks to the loading point while empty racks are being brought back to the hardening room. The entire platform is protected by a canopy which extends 4 feet beyond the edge of the platform. The canopy is 13 feet above the platform which is 3 feet above ground level.

The trucks are equipped with 3-ton electrically operated refrigerating units. There are electrical plugs for these refrigerating units in the garage.

Boiler and refrigeration equipment rooms.—The boiler and refrigeration equipment rooms are adjacent to the tanker-receiving area and to dry storage room A. The boiler room has an area of 736 square feet. In this room are the hot water tank (71), boiler feed water system (72), and two steam boilers (69, 70).

The refrigeration equipment room (1,600 square feet) adjoins the boiler room. Here are located a 30-ton ammonia booster compressor (63), a 69-ton ammonia booster compressor (64), a 53-ton ammonia compressor (65), a 75.4-ton ammonia compressor (66), a liquid ammonia intercooler (67), an ammonia receiver (62), an air compressor (88), and an electric panel board (68) for the refrigeration control system. A 130-ton evaporative condenser (76) is located outside of the building next to the boiler room.

The floors of these rooms are 3 feet below those of the rest of the plant. The ceiling height is 17 feet. The walls are painted concrete block.

Garage and cabinet shop.—The garage and cabinet shop are in a separate building, 60 feet by 154 feet, adjacent to the plant proper. An area 60 feet by 88 feet is used for mechanical repairs and garage space for company vehicles; the rest is used as a cabinet shop.

Provision for Plant Expansion

This layout can be expanded to double plant production without disrupting flow patterns and with minimum additional construction.

The receiving facilities are adequate.

During the peak month of July, approximately thirteen 300-gallon batches of mix are prepared each processing day. If it is assumed that a maximum of 14 batches will be made, approximately 160 gallons of corn sirup will be required. Since the corn sirup tank holds 2,800 gallons, the supply is enough for 18 days of freezing in July, or nearly a month. Therefore, when the plant capacity is doubled, corn sirup will have to be ordered twice each month instead of once.

To make fourteen 300-gallon batches of mix requires approximately 740 gallons of liquid sugar. The liquid sugar tank holds 2,800 gallons, or nearly enough for 4 mixing days in July. When the plant capacity is doubled, the liquid sugar must be ordered twice each week instead of once.

The amount of 40-percent cream required to make fourteen 300-gallon batches of mix is 1,172

gallons, and the amount of 30-percent skim milk concentrate is 1,413 gallons. Since the capacity of these two storage vats is 1,500 gallons each, another set of vats (6, 7) will be needed when plant volume is doubled.

Two 600-gallon mix assembly tanks (10, 11) will replace the two 300-gallon tanks (8, 9).

To process the doubled amount of mix, the 600-gallon homogenizer will be replaced by a 1,200-gallon machine (27), and additional plates will be added to the plate pasteurizer and cooler (24). The steam infuser heater (20) and vacuum deaerator (28) will operate at double the initial capacity.

For storing the additional mix, one 1,500-gallon mix storage tank (33) and one 3,000-gallon tank (34) will be added.

Another 900-gallon 3-cylinder freezer (39) will be placed next to the present freezer (38). Another tube (13) will be added to the 180 gallon-per-hour tube freezer (40).

Since the fruit feeder is used only part of the time, there will be no need for another when plant capacity is doubled.

A second mix flavor tank (37) will be necessary to handle the increased volume. The additional tank will have three compartments each with a capacity of 250 gallons.

Total ice cream freezing capacity will be 1,800 gallons per hour at 85 percent overrun (not including freezer on novelty line). The total capacity of the filling machines is 2,400 gallons per hour. By using all three filling machines at the same time, no additional equipment will be needed.

The overwrap operations can proceed more rapidly when the filling capacity is increased, and no additional equipment will be needed.

The present novelty machine will be replaced with one of doubled capacity (50a).

For the refrigeration system, the 30-ton ammonia booster compressor (63) will need to be exchanged for a unit with 60-ton capacity (63a); and a 68.85-ton booster compressor (81), a 113.70-ton second-stage compressor (82), and a 130-ton evaporative condenser (77) will have to be added. All other equipment in the refrigeration system is adequate to handle the increased load.

One 50-b.hp. (boiler horsepower) steam boiler will be replaced with a 100-b.hp. boiler (83) when needed.

The hardening room and overhead conveyor system (56) should be doubled in size.

Storage room B will have to be doubled in size by the extension indicated on the layout.

Space is allowed in the control panel for additional controls. Future mix assembly tanks 10 and 11 will be operated by the same controls that operate initial mix assembly tanks (8, 9).

Plant Site

The same factors are used in determining a proper site for this plant as were used for the smaller ice cream plant. The site should be on or near a major highway and near the principal market. For freedom of truck movement around the plant and for a limited amount of landscaping in front of the building, a plot 400 feet wide and 425 feet deep is recommended (fig. 7). This area of 170,000 square feet, or approximately 4 acres, provides ample room for expansion.

The plant is located near the center of the site. A 25-foot-wide concrete driveway brings traffic in on one side of the plant, encircles the plant, and returns to the highway on the other side. Aprons connect the driveway with the loading dock and receiving area. A garage 75 feet by 156 feet is located at the rear, near the side street.

There is ample parking space on two sides of the area for trucks and for employees' and visitors' vehicles. All parking areas should be either hard surfaced or covered with crushed rock. The area in front of the plant should be attractively landscaped.

How the Plant Operates

The major operating cycles involved in manufacturing ice cream and ice cream novelties are (1) receiving raw products; (2) manufacturing ice cream, which includes assembling and processing mix, freezing, packaging, and storing; (3) manufacturing novelties, which includes assembling and processing mix, freezing, packaging, and storing cups of ice cream, and freezing, forming, packaging, and storing ice cream bars and sticks; (4) loading out; and (5) cleaning the equipment. Some operations or parts of operations are automated and operated from a control panel. Other operations are mechanized. Among the automated operations are checking the weight of products in the raw ingredients tanks, assembling mix ingredients, pasteurizing and deaerating, and cleaning. Figure 8 shows the flow of ingredients and ice cream from receiving through packaging.

Tank trucks with cream and concentrated skim milk arrive at the plant in the late afternoon before each mix-making day. The 150-gallon-per-minute centrifugal pump (3) unloads a tanker into one of the previously washed and sanitized storage tanks (4, 5) in about 8 to 10 minutes. The truck and pump are connected by sanitary pipelines. While the tankers are being unloaded, a sample of cream is taken to the laboratory, where it is checked for flavor, temperature, acidity, and fat content. A sample

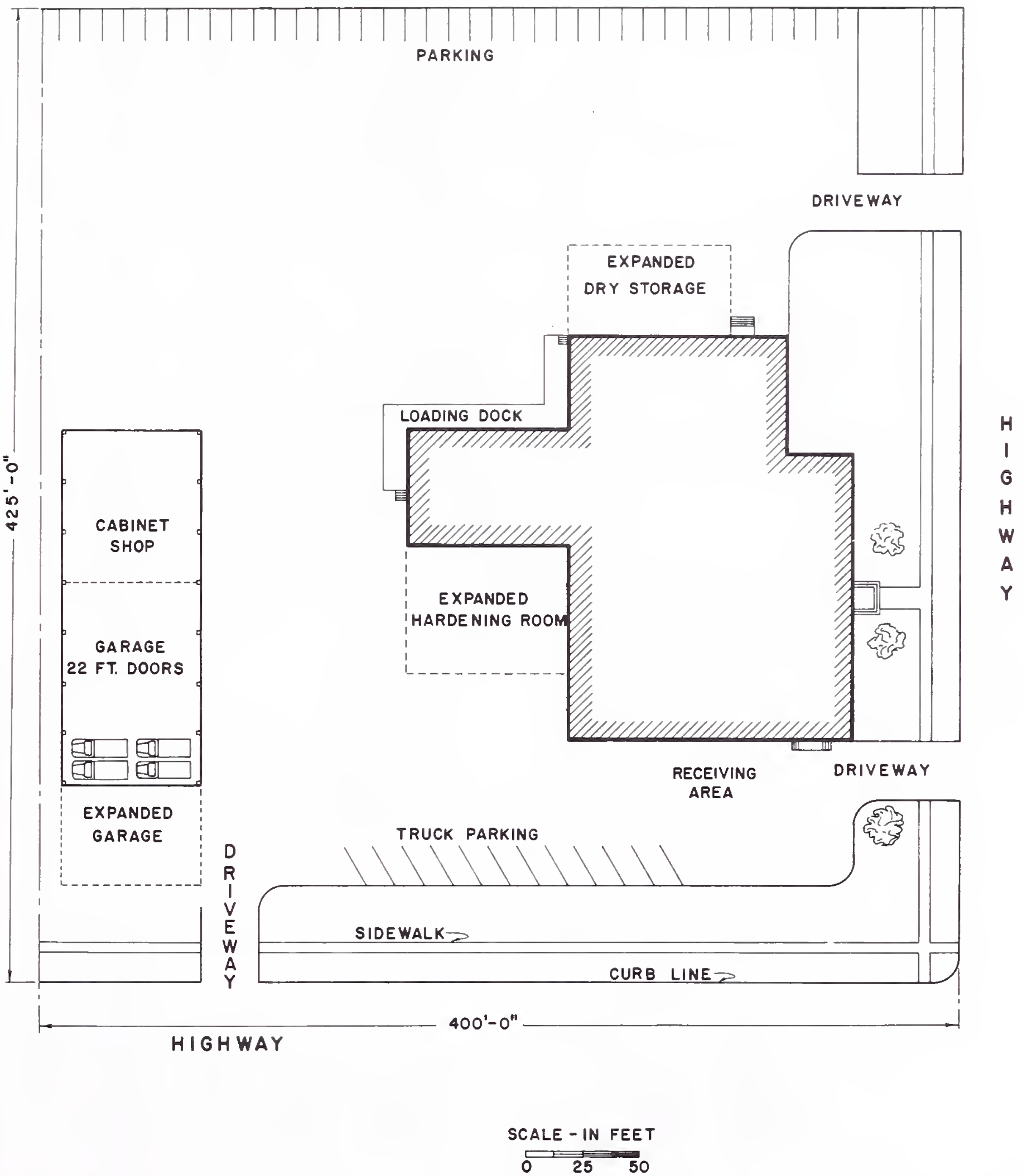


FIGURE 7.—Suggested layout for the site of an automated ice cream plant manufacturing 1¼ million gallons of ice cream and novelties annually.

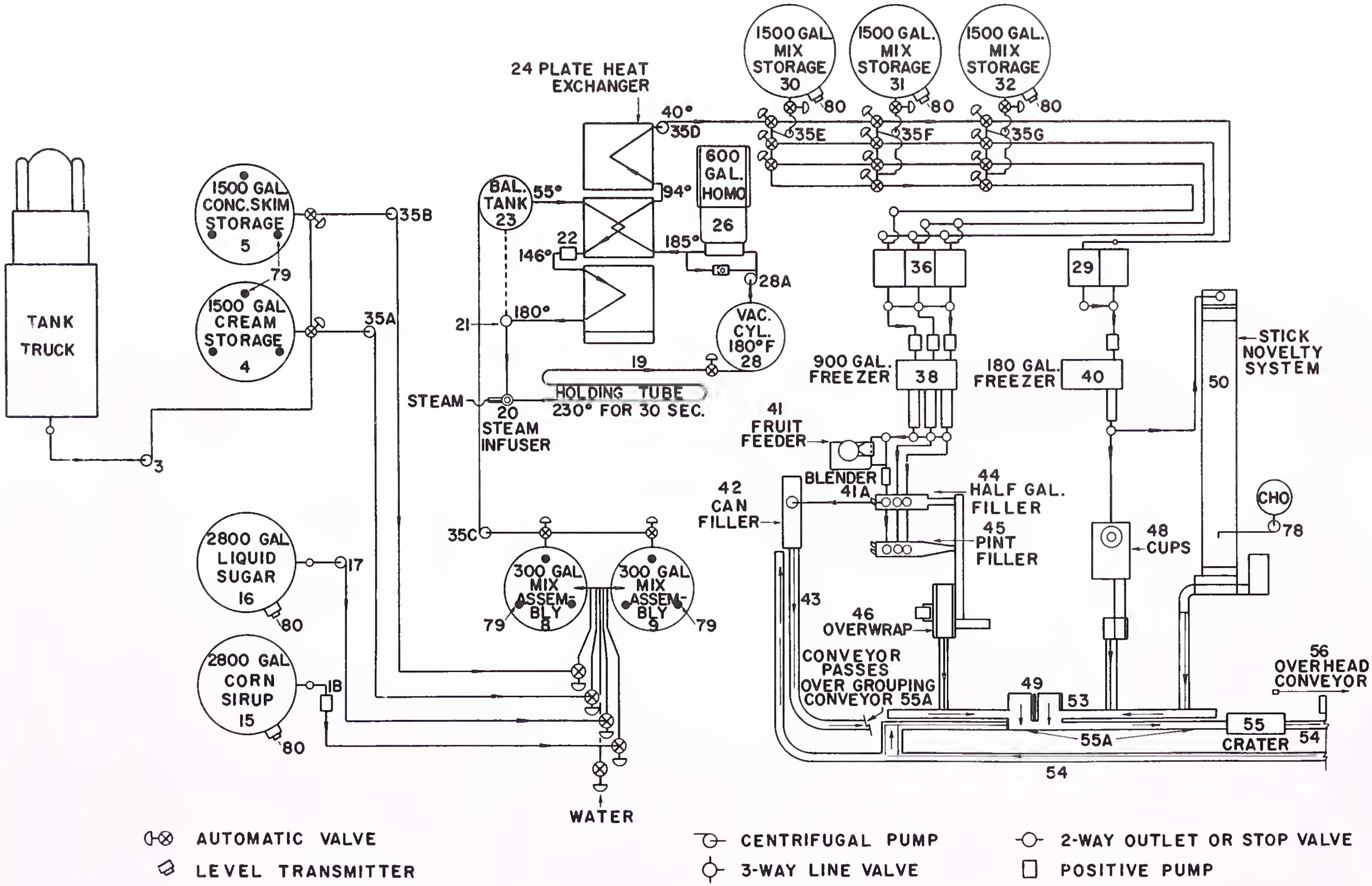


FIGURE 8.—Flow of mix ingredients and ice cream from receiving through filling of packages.

of the milk is checked for flavor, temperature, acidity, and total solids.

The corn sirup deliveries are less frequent, about once each month, and the liquid sugar deliveries about once each week. These products are unloaded in about the same way as the milk products, except that the corn sirup tanker uses its own pump. The corn sirup is stored in tank 15 and the liquid sugar is stored in tank 16. Pipelines, running through the passageway to the platform, connect the pump on the corn sirup tanker and the pump for liquid sugar (17) with the storage tanks.

Manufacturing Ice Cream

The manufacture of ice cream involves assembling and processing mix, and freezing, packaging, and storing ice cream.

Ice cream mix is assembled and processed automatically from the control panel (fig. 9).

Assembling and processing mix.—The first section of the control panel contains the instruments for checking weights and taking inventory of liquid mix ingredients.

Weights of cream and skim milk are shown at upper right in the first section of the control panel under "weight indicator."

Two methods are used to check the weights of the raw products received. A load cell system (weight sensing) is used for checking the weight of the cream and concentrated skim milk in storage tanks 4 and 5. Under proper operating conditions this method, according to the manufacturer, has an accuracy of one-fourth of 1 percent of the full-scale reading. The second method is based on level sensing and, again according to the manufacturer, has an accuracy of one-half of 1 percent. It is used for measuring the amount of product in the liquid sugar, corn sirup, and mix storage tanks. To obtain maximum accuracy by either method, the tank must be at least 25 percent full.

The level-sensing system uses a pneumatic pressure transmitter (80). A thin flexible membrane flush with the inner surface of the tank separates the pressure of the liquid in the tank from the counterbalancing pressure of air in the level-sensing system. The air pressure required to counter-balance the pressure of liquid in the tank actuates the liquid indicator in the manometer tube, which can be calibrated to read in pounds or in gallons. The same pressure can also be used to actuate pressure switches, which can control other operations.

To check the weight of either cream or concentrated skim milk, the tank selector switch is set to tank 4 or 5. The load cells under the tanks produce a microvoltage signal proportional to the weight in the tank. This makes it possible to read the weight of cream or condensed milk in pounds on the weight indicator.

The amount of liquid sugar or corn sirup in tanks 15 and 16 and finished mix in tanks 30, 31, and 32 can be read on the manometer at the left in the first section of the panel, by depressing the tank selector toggle switch for each of these tanks. The five level indicators show at a glance the approximate amount of product in each of the tanks. The pilot lights just above the level indicators are illuminated when a product is being pumped into or out of one of the storage tanks (15, 16, 30, 31, or 32).

The second section of the control panel carries the instruments for assembling the mix. The multipoint recorder at the top of the panel records the pounds of each ingredient added to a mix assembly tank (8 or 9) and, in addition, records the total pounds of mix in the tank. This is a permanent record, and at the end of each day's operation it is given to the plant accountant for his records and for inventory control purposes.

The mixing operation is scheduled from 10 a.m. to 6 p.m.; it requires 6¾ hours of operating time. A 300-gallon batch of mix can be assembled automatically in 10 to 15 minutes. The first batch is pasteurized and homogenized immediately after assembling, and then held in one of the refrigerated storage tanks (30, 31, 32) until the following day, when it is frozen. Successive batches are processed continuously on a 30-minute schedule.

On the average, ten or eleven 300-gallon batches are ice cream mix, and two or three 300-gallon batches are sherbets and ices.

Tank 8 or 9 is selected for preparing the 300-gallon batch of mix. The vat selector switch at the left of the second section of the panel board is thrown to the selected vat number. The required amount of each ingredient of the mix is then set on the digit setters located below the multipoint recorder.

The amount of each ingredient depends on the formula used. For 300 gallons of mix of the composition assumed for this plant, the following ingredients will be needed:

Ingredients	*Pounds*
40-percent cream	686.4
30-percent concentrated skim milk	928.8
Liquid sugar	524.8
Corn sirup	115.2
Stabilizer [1]	8.3
Emulsifier [1]	1.5
Water	480.0
Total mix	[2]2,745.0

[1] These ingredients are manually added.
[2] 300 gallons.

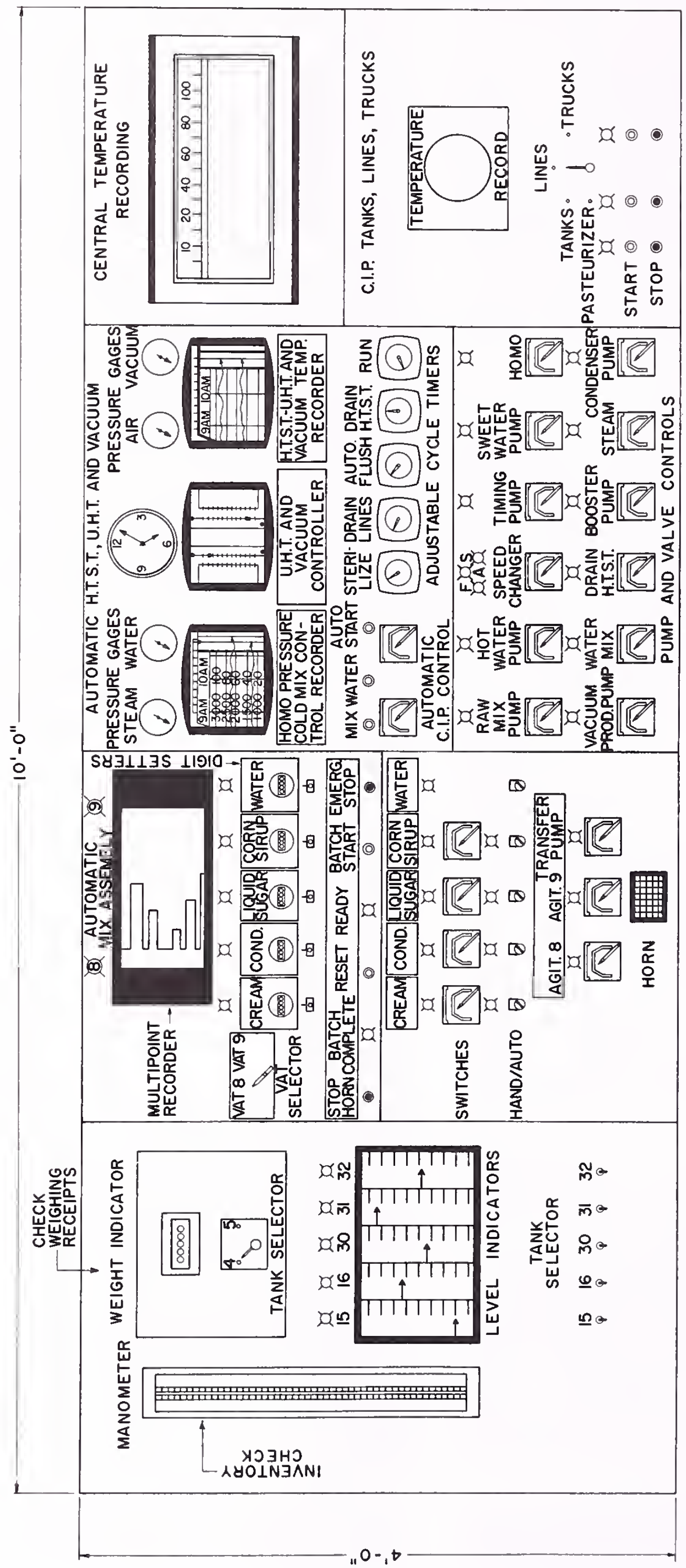


FIGURE 9.—A suggested control panel for an automated ice cream plant manufacturing 1¼ million gallons of ice cream and novelties annually.

After the amount of each ingredient is set on the digit setters, the switch for each ingredient is placed on automatic, and the agitator switch for the selected vat (8 or 9) is set to on. (Each valve and pump switch has a manual and an automatic position, for safety.) The reset button is then pressed. When the "ready" light comes on, the "batch start" button is pressed. The raw products then will be pumped in sequence into the selected mix assembly vat (8 or 9).

An emergency button is provided to stop the process if desired. Two other safety measures are provided: Circuitry interlocks to prevent a batch from being started when the mixing vat is full, and an arrangement of the circuitry that will automatically stop the unit if one of the ingredients is in short supply and the pump runs dry.

After the batch is made, a horn sounds and can be stopped only by pressing the "stop horn" button, at which time the "batch complete" light comes on. The transfer pump switch at the lower right side of the second panel is then used to transfer the assembled mix to the infeed balance tank (23) of the pasteurizer (24).

When successive batches of the same composition are to be run, the vat selector switch is then turned to the other vat (8 or 9), the "reset" and "batch start" buttons are pressed, and the process is repeated. "Omit" switches are provided so that any ingredient may be omitted if desired.

The assembled mix is pumped (35c) into the balance tank (23), where a float valve maintains it at a constant level. At this point the raw mix temperature is approximately 55° F. (fig. 8). The mix is drawn through the regenerating section of the pasteurizer (24) by the positive timing pump (22) at the rate of 600 gallons per hour. The mix enters the heating section of the pasteurizer at 146° and leaves at 180°. It then flows through the flow diversion valve (21), where it is returned to the balance tank if it is below the preset temperature (in this case, 180°). If not returned to the balance tank, the mix passes through the steam infuser heater (20), where the temperature is rapidly raised to 230° by the addition of culinary steam.

The mix next passes through the 30-second holding tube (19), maintained at 21 pounds gage pressure, and into the vacuum deaerator (28). The deaerator operates at 14½ inches of mercury and at a temperature of 180° F. This drop in pressure removes the steam previously added and volatile compounds, such as feed odors. Thus, mix temperature is reduced from 230° to about 180°.

The mix is then fed by centrifugal pump (28a) to the homogenizer. The pressure of the homogenizer is set at 2,000 pounds per square inch on the first valve and 500 p.s.i. on the second valve. The homogenizer will not operate efficiently unless the inlet pressure is at least equal to the sum of the resistance to flow and to acceleration. Since the pump cannot be regulated to feed the exact quantity required, it is regulated to feed about 5 percent less mix than the homogenizer can handle. This 5 percent is supplied to the homogenizer by a line that returns mix from the homogenizer discharge to the inlet line. Whenever the inlet pressure drops below 15 pounds, mix is supplied from the high pressure discharge line. A check valve in the line prevents unhomogenized mix from bypassing the homogenizer.

The mix temperature rises 5° to 185° F. owing to frictional heat caused by the pressure exerted by the homogenizer.

Recorders on the third section of the control panel register the temperatures and pressures involved in the mix processing. These enable the operator to tell at a glance whether the equipment is working properly.

The UHT (ultrahigh temperature) and vacuum controller regulates the ultrahigh heating temperature and controls conditions in the vacuum chamber. The third section of the panel also contains a control recorder for automatically controlling the mix homogenizing pressures and for recording the pressure.

From the homogenizer the mix passes through the regenerative section of the plate pasteurizer (24) and then through the final cooling section of the plate.

The mix is cooled from 185° F. to 94° in the regenerative section of the plate pasteurizer and then to 40° in the final cooling section. Sweetwater at 34° from the ice builder (52) is circulated through this section by the centrifugal pump (14).

The cooled mix is pumped by centrifugal pump (35d) to one of the three 1,500-gallon insulated and refrigerated storage tanks (30, 31, or 32). The 750-gallon flavor tank (36) or the 250-gallon flavor tank (29) can also be used for storage since they are both insulated and mix temperature does not usually rise more than 2° F. They are especially suited for ice, sherbet, or chocolate mix storage because of the usually smaller batch size.

On the fourth section of the control panel is the "Central temperature recording" device, which enables the operator to check the temperature of the raw ingredients and the mix in the various tanks where they are stored.

Freezing, packaging, and storing ice cream.—The freezing operations are manually controlled. To start the freezing operation, the mix is pumped (35 e, f, g) from the storage vats (30,

31, and 32) to the flavor tank (36). The desired flavor is added; the flavored mix is then pumped to the three-cylinder freezer (38), each cylinder of which has a freezing capacity of 300 gallons of ice cream per hour at 85 percent overrun. A volume of 900 gallons per hour of ice cream at 85 percent overrun requires 486 gallons of mix per hour; therefore, the flavor tank (36) provides about 1.5 hours' supply. Separate flavors can be run through the three cylinders of the freezer or all three can be used for the same flavor. The freezer has its own mix pump.

The fruit feeder (41) and blender (41a) are connected near the freezer so that ice cream can be passed through the fruit feeder as needed.

When fruit ice cream is being made, enough fruit is added to equal 10 to 15 percent of the weight of the mix. It is important that the juice be drained and added to the flavor tank to get even distribution of the flavor. When all three freezing cylinders are being used to make one fruit-flavored ice cream, the ice cream from one freezing tube is passed through the fruit feeder, where sufficient fruit is added for all three tubes. The discharge from all three is then mixed in the blender (41a). The flavored ice cream is pumped by the freezer either directly to one of the packaging machines or through the fruit feeder and blender to the packaging machine.

Figure 10 shows how the packaging machines can be scheduled to produce the volume needed for a peak month.

The $2\frac{1}{2}$-gallon-can filler (42), operating at 900 gallons per hour, handles the capacity of the entire freezer. After the cans are formed by the can former (91), a worker places them in filling position and covers the filled cans. He puts two cans in a basket and places the basket on a conveyor (43), which leads to the load-on position of the overhead conveyor (56). Conveyor 43 passes over the package grouper (49) and package crater (55). Empty wire baskets are delivered to filler 42 from the loading platform by conveyor 54.

When half-gallon containers are being filled, the ice cream is pumped by the freezer, either directly or through the fruit feeder and blender, to the filling machine (44). The machine requires little attention, other than keeping the magazine full of folded cartons.

The pint-carton filler (45) operates at a safe maximum speed of 500 gallons per hour. At this speed, one attendant is required.

Both the half-gallon and pint packages are conveyed to the overwrap machine (46), which wraps them with paper in gallon bundles. The wrapped bundles are then moved by conveyor (53) to the grouper (49), which automatically collects eight 1-gallon bundles and sends them on the crater infeed belt (55a) to the package crater (55). The package crater automatically places the eight bundles in a basket.

At the discharge of the package crater (55), an operator hooks the wire basket onto the conveyor. Hooks are spaced on the overhead conveyor (56) a distance equal to the width of the basket plus 2 inches in direction of travel. The hooks are conveyed along the track at the rate of $11\frac{1}{2}$ feet per minute until they reach the hardening room area. The baskets containing the soft ice cream are automatically carried into the plenum chamber for quick hardening.

As the baskets pass the preselected storage line, an air-actuated "finger" lifts them off the infeed line and places them on the storage line. The storage line moves the basket forward at the rate of $3\frac{1}{2}$ feet per minute until there is enough space for the next basket. Then the storage line shuts off. The loading cycle is repeated until the selected line is filled. This stops both the storage line and the infeed line automatically. The operator then selects another storage line and the same sequence takes place.

There are 30 crosslines, each with a capacity of 50 baskets, that engage the infeed line at right angles. Total storage capacity of the plenum chamber is 1,500 baskets. Each basket holds 8 gallons of packaged goods or 8 dozen novelties. When 900 gallons of ice cream and 500 dozen novelties are being made per hour, 175 baskets will be needed, 112 for the ice cream and 63 for the novelties. About 1,100 baskets are filled and conveyed into the plenum chamber during a full day's operation, and conveyor lines for 400 baskets remain available for the first 3 hours' operation on the following morning.

Two conveyor switches (84, 84a) are used to control the movement of the baskets in the system. The selector switch (84) at the inlet of the hardening room is used to route the baskets to the line selected for that product or flavor. The selector switch (84a) on the loading platform is used to route the packages or novelties called for to the platform. The hardened product is automatically fed down the conveyor (pitched 4 inches per foot) to the lower part of the hardening room at the rate of $11\frac{1}{2}$ feet per minute. Here the product is either stacked on pallets or truck-loading racks. A special order can be sent to the loading dock via the overhead conveyor. The baskets remaining on the conveyor lines after the trucks have been loaded are emptied and palletized when the hardening room worker has time.

The hardened ice cream is stacked on 39- by 60-inch pallets, which are placed on angle iron racks. On each pallet are seven layers of pack-

ages, 40 gallons to each layer. The pallets are moved and stacked with a battery-powered lift truck.

Manufacturing Novelties

Approximately the same procedures as described for producing ice cream are used for assembling, processing, and freezing mix for novelties.

The novelty mix is usually stored in two-compartment storage tank 29. Each compartment holds 125 gallons. This tank supplies the mix for the 180-gallon-per-hour single-cylinder continuous freezer (40), which freezes the ice cream for the 4-ounce cups and slushes the mix

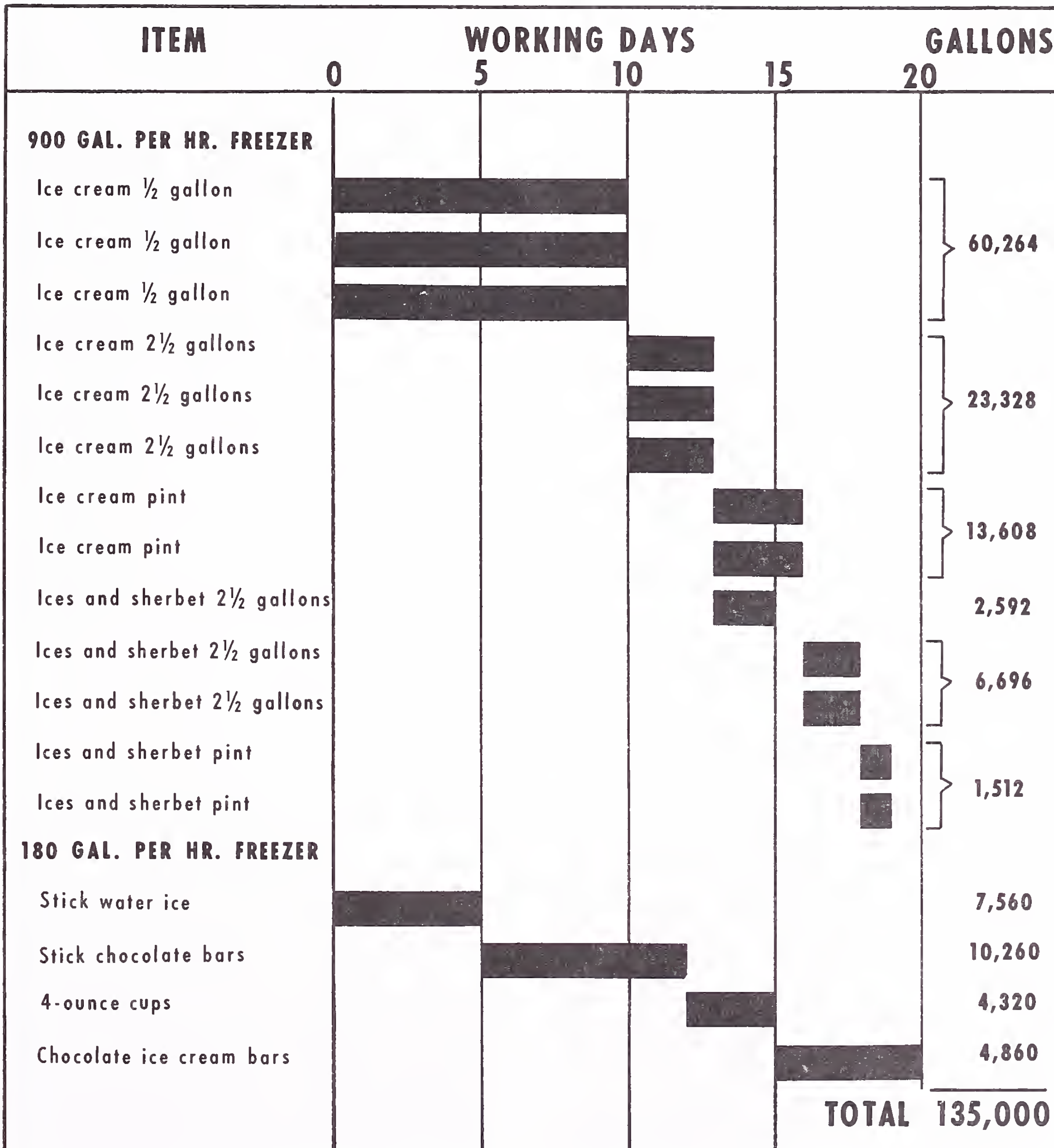


FIGURE 10.—A freezing and packaging schedule for a peak month of 135,000 gallons of ice cream and novelties.

for bars and stick novelties. Ice cream bars are made at the rate of 500 dozen per hour. At the slush freezing temperature of 25° to 26° F., the freezer can produce 250 gallons per hour for bar and stick novelties.

The machine (50) for making novelties combines several operations in one unit covering 70 square feet of floor space. It operates automatically and is capable of producing a variety of sizes and shapes. The machine automatically performs eight functions:

Filling the molds.—The stainless steel filler, connected by pipeline with the freezer (40), measures any predetermined amount between 2 and 5 ounces into the molds. It will handle water ice, sherbet, ice cream, ice milk, or liquid fudge mixes.

Stick inserter.—As the filled molds, six in a row, move forward through the brine tank, they reach the second position, where a row of sticks is inserted.

Hot water defroster.—The molds continue moving forward through the brine, and the freezing process is completed before they reach the defroster. Hot water circulates from a thermostatically controlled steam-heated supply tank through a defrost pot. As the mold cups advance the defrost pot is raised, immersing the confection-filled mold cups in hot water.

Confection extractor.—With the upward movement of the defrost pot, the extractor bar is lowered to engage the full row of confections and extract them from the molds. The defrost pot is then lowered, as the confections move along in cycle.

Chocolate dipper.—The row of molded confections advances from the extractor to the dipper, where the bars are momentarily submerged in melted 95° F. chocolate, the temperature of which is automatically controlled. A pump (78) circulates the chocolate constantly from the pot to the supply tank.

Bagger.—The coated bars move forward to the bagger, where an air-filtered blower system opens six bags at a time, as they are positioned in the bag magazine below in direct line with the frozen confections to be discharged. As the machine cycles, extractor blades release the products into the open bags. A conveyor delivers each series of bagged bars in uniform rows to the packaging station.

Mold washer.—As the mold cups are cycled back through the machine, they pass to the washer where they are prerinsed, washed with hot water, and rinsed. The temperature of the water is automatically controlled.

Freezing system.—The freezing tank contains 180 gallons of cold (−25° F.) brine, which is kept circulating by a pump (47) through distributor pipes to create turbulent flow. The machine has a capacity of 450 to 600 dozen novelty items per hour and requires 294 mold strips. It requires 26.5 tons of refrigeration at a capacity of 500 dozen 3-ounce water ice molds per hour. This is the peak refrigeration requirement.

The last step in the process is placing the molded bars in cartons of two dozen. The machine automatically forms, positions, closes, seals, and imprints 1,000 or more cartons per hour. Two workers are required for the entire operation, from filling the molds to sealing the bars in labeled cartons.

Chocolate-coated bars without sticks are processed in the same manner as bars with sticks, except that a holder similar to the stick holder positions two V-shaped wires in the ice cream. The wires are used for withdrawing the bar from the mold and holding it for coating. The coating is omitted with water ice bars.

The cartons of molds are moved by a conveyor at the end of the machine to conveyor 53 and then to the grouper (49), where six 2-dozen cartons are accumulated. The grouper transfers them to the crater infeed belt (55a), and the package crater (55) places them in wire baskets from the wire-basket conveyor (54). The wire baskets are manually hung on the overhead conveyor (56) at the loading position and then moved into the hardening room.

When 4-ounce cups are being filled with ice cream, sherbets, or ices, the mix is pumped from the flavor tank (29) through the 180-gallon single-tube freezer (40) and to the cup filler and boxer (48), at the rate of 250 cups per minute. The boxes then move by a conveyor at the end of the cup filler to conveyor 53 and to the grouper (49).

Novelties are scheduled to be made at the same time packages are filled with ice cream. The crater (55) places both novelties and ice cream packages in wire crates at the same time. To prevent mixing novelties and ice cream packages, the grouper (49) lets through a full basket of one kind of product at a time. From one side it accumulates packages and from the other side novelties. When eight 1-gallon packages have accumulated, it shunts them onto the belt that takes them to the crater. At the same time, an empty wire basket on the chain conveyor below also enters the crater. When both basket and packages are in place, two microswitches engage and the packages are deposited in the wire basket. Interlocking switches prevent novelties and packages from being shunted onto the crater infeed belt at the same time.

Loading Out

The delivery trucks are loaded from the platform next to the hardening room. Loading is usually done in the late afternoon or evening. Each truck carries five ice cream storage racks mounted on casters; each rack is 25 inches wide, 47 inches long, and 64 inches high. There are three shelves on each rack, and each rack holds 200 gallons of ice cream.

Empty racks are returned from the route delivery and are exchanged for racks loaded with the needed ice cream products, previously assembled by the hardening room worker. The worker loads the racks, using the order sheet prepared daily for each route. A copy is given to the driver so that he can check his load. If there are more orders than the racks will hold, additional ice cream is placed on the truck shelves.

When necessary, special orders can be sent directly to the loading platform by the overhead conveyor (56). The selector switch (84a) on the loading platform routes the products needed directly to the platform.

Cleaning the Equipment

The controls for CIP cleaning of the milk products truck tanks, the various tanks involved in processing and storage, and the sanitary pipelines are located on the lower half of the third and fourth sections of the control panel. A temperature recorder is used to record the time and temperature of each cycle (flush, wash, and rinse) of the CIP circuit.

Two tank CIP cleaning systems (73, 57) clean certain groups of equipment.

System 73 with CIP connecting stations (2a, 2b) cleans the tankers, the raw milk products storage tanks, sugar and sirup tanks, mix assembly tanks, short-time pasteurizer, mix storage tanks, and the interconnecting piping.

System 57 is used to clean the mix flavor tanks; it uses a portable CIP return pump (85) to circulate the solutions to these tanks. This system can also be used to clean the three mix storage tanks if system 73 is in use when these tanks need cleaning.

To operate the CIP system, all switches shown on the bottom half of the third section of the control panel are set to "automatic." The button labeled "water" is pressed to start the system on water, and the "mix" button is pressed to start the mix supply pump so that switching from mix to water can be made automatically. The "sterilize" timer is adjusted to the desired sterilizing period.

The selector switch on the fourth section of the panel is set to the item to be cleaned (such as "tanks"), a pipe connection is made, and the start button is pressed. All of the tanks have built-in spray balls that permit cleaning with a minimum of connection. The instruments on the panel start a preset and predetermined flush, wash, and rinse cycle. When once determined by trial, these time cycles are kept constant.

To clean a truck tanker, the CIP transport tank washer (12) is lowered into the tanker manhole, a connection is made at the CIP connecting station (2a), and the tanker outlet is connected by hose to the CIP return pump (85a). The selector switch is set on "trucks" and the start button is pressed. A sequence selector switch automatically goes through a rinse cycle, an alkali cleaning cycle at a predetermined temperature and time (usually about 120° F. for 15 to 20 minutes), a rinse and a sanitizing solution for 5 minutes (usually 200 p.p.m. of chlorine solution).

Cleaning of "tanks" and "lines" is programed in the same manner.

The sequence for the plate pasteurizer is a warm rinse, hotter solutions (160° F. acid cleaner circulation) for 15 to 30 minutes, drain, an alkali cleaner at 160° F. for 15 minutes, a clear rinse, and a sanitizing solution.

Ordinarily, only alkali is used to clean cold mix circuits. On pasteurizing equipment and other equipment that comes in contact with the hot mix, acid solutions may be needed for proper cleaning.

In the rear of the panel are connections that permit the operator to instantly change the time of any part of a cleaning or sanitizing operation. The drain time on a circuit depends on how far the automatic drain valve is from the solution tank.

The unit will also automatically flush and drain itself at the end of the day's run, through the use of the cycle timers on the control panel. The cycle timers are preset to appropriate time periods to meet plant operation needs. It is necessary only to throw the switches indicated to start the cycle.

Two electrical interlocks prevent operation if (a) the connector at the hookup station (2) is not properly connected, (b) if the selector switch is at the wrong position, or (c) if a microswitch circuit is closed because a manhole door on a tank has not been opened, endangering tank collapse when a cold rinse follows a high temperature.

Some equipment must be dismantled and cleaned.

The freezing cylinders and pumps are rinsed with water from system 57; then the parts are disassembled and put into cleanup tank 86,

which is on casters and can be moved to any desired location. The short sections of piping, as well as fruit feeder parts and package filler parts, are placed in the cleanup tank and cleaned with system 57 and return pump 85.

Cleanup tank 87 is used in a similar way for parts such as the homogenizer strainer and plungers and for small parts which must be disassembled in this area of the plant.

Labor Requirements

Table 5 shows the various operations to be performed and the number of workers required in a nonautomated and an automated plant on a typical day during the peak season. Each employee works 8 hours and takes 30 minutes for lunch.

The automated plant employs 17 workers and the nonautomated plant 25.

The supervisor assists or arranges for assistance if a temporary labor shortage occurs because of the absence of a worker. Two freezer men are required at certain periods in the automated plant, but much of their time is available for maintenance or for relieving other workers.

In the automated operation, one worker has ample time to clean the HTST (pasteurizing) unit, tanks, and lines with the cleaned-in-place (CIP) system and to wash the homogenizer and freezers. In the nonautomated plant, three workers would be needed.

TABLE 5.—*Job classification and workers needed in automated and nonautomated plants manufacturing 1 million gallons of ice cream and 250,000 gallons of novelties annually*

Job classification	Number of workers needed	
	Nonautomated plant	Automated plant
Supervision	1	1
Receiving, mix assembly, and processing	2	1
Freezer operation, maintenance	2	2
Novelties and packaging	6	3
Crating and conveying	2	1
Dry storage	½	½
Hardening room and loading	3	2
Cleanup	3	1
Laboratory and records	1	1
Loading out	1½	1½
Engineers	3	3
Total	25	17

Two workers are required when novelties are made, wrapped, and boxed automatically, and four are needed when these operations are performed manually. Two workers are required for filling pint and half-gallon packages without an overwrapping machine, but with the automated equipment, one has time enough to help with other operations if need arises.

Three maintenance engineers are required for both types of plant. However, in the automated plant only one must be on duty at all times the plant is operating, rather than all three as required for nonautomated operations. This flexible use of maintenance engineers provides servicing for equipment on days when the plant is closed, without having to pay overtime.

One of the striking differences between the two plants will be the reduction of workers' physical exertion in performing their duties in the automated plant. In the hardening room of the automated plant, for example, with the overhead conveyor system of loading and unloading, it is easier for two men to palletize and load trucks than it is for three men to perform the same duties in the nonautomated plant.

By the use of CIP methods of washing and sanitizing, the number of workers can be reduced from three to one, and the job is much easier to perform.

The time necessary for supervision and laboratory tests will be the same for both plants, although the supervisory duties will differ somewhat. A supervisor, as well as the key men, in an automated plant needs to know more about mechanics and instrumentation than a supervisor in a nonautomated plant.

The automated plant produces 35.3 gallons of ice cream per man-hour, and the nonautomated plant produces 24 gallons per man-hour, on a yearly basis.

Costs and Possible Benefits of Labor-Saving Devices

The equipment required for the automated plant to reduce the labor requirements would consist of the central control panel (1), automatic mix assembly system, load cells (79), homogenizer pressure controller, CIP system (12, 57, 58, 73, 74), automatically operated sanitary valves to control product flow, overhead conveyor system (56), automatic overwrap machine (46), package grouper (49), and package crater (55). The estimated cost of the equipment (based on 1963–64 prices) would be $127,500 more than that for equipping a nonautomated plant.

It is estimated that the automated ice cream plant handling 1 million gallons of ice cream and 250,000 gallons of novelties annually could operate with eight fewer workers than a nonautomated plant handling the same volume. Based on an assumed cost of $6,500 annually per worker (salary plus fringe benefits), the annual savings should amount to $52,000. If 20 percent is allowed annually for ownership and operation costs (depreciation, maintenance, insurance, taxes, and interest), the costs of the additional equipment would amount to $25,500 and an annual saving of $26,500 would result.

Production per man-hour should be higher in the automated plant. Based on an annual production of 1,250,000 gallons, the production per man-hour is, roughly, 60 percent greater for the automated plant than for the nonautomated plant.

Machine-controlled operations should result in a reduction of the in-plant losses of product. They should also provide for more standardized production than is attained in a nonautomated plant using conventional equipment. No data are available for estimating the savings for these items.

APPENDIX: REFRIGERATION, HEATING, VENTILATION, AND AIR CONDITIONING

Plant Manufacturing 200,000 Gallons of Ice Cream a Year

Refrigeration System

The refrigeration system for an ice cream plant should be adequate for cooling ice cream mix, maintaining holding tanks and contents at the required temperature, and freezing and holding finished ice cream products. Three refrigeration systems are suggested: A Freon[7] system for an ice builder, a Freon system for cold-wall storage tanks, and an ammonia system for the ice cream freezer and hardening room. A diagram of the suggested refrigeration system is shown in figure 11.

The refrigeration calculations are based partly on data contained in the "Mechanical Engineers' Handbook" (pp. 79, 303, and 2154), "Heating, Ventilating and Air Conditioning Guide" (p. 254), and "Refrigeration Engineering Application Data."[8]

Cold-wall storage tanks.—It is assumed that the various products enter the storage tanks (4, 5, 14) at 41° F. and are to be cooled to 38°

[7] Trade names are used in this publication solely to provide specific information. Mention of a trade name does not constitute a guarantee or warranty and does not signify that the product is approved to the exclusion of other comparable products.

[8] MARKS, LIONEL S. MECHANICAL ENGINEERS' HANDBOOK. 4th ed. illus. 1941.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS. HEATING, VENTILATING AND AIR CONDITIONING GUIDE. 1947.

SEGAL, S. CHARLES. REFRIGERATION LOAD CALCULATIONS—II. TEMPERATURES BELOW 32° F.—REFRIG. ENGIN. APPLIC. DATA 12. Refrig. Engin. Vol. 39, No. 4, Sec 2. April 1940.

It is also assumed that there will be a 2° rise in temperature every 24 hours owing to refrigeration loss through the tank walls. It is therefore necessary to cool the storage tanks 5° per day, which is done in a 16-hour cooling period. The formula for computing the refrigeration load on the storage tank is—

$$\text{B.t.u. per 24 hours} = \text{Gallons of product} \times \text{Weight of 1 gallon} \times \text{Specific heat} \times \text{Temperature change} + \text{Agitator load}$$

The agitators are assumed to run 16 hours per 24-hour period. Each tank is equipped with a 1-horsepower agitator, assumed to operate at 85 percent efficiency. The formula for computing the refrigeration required to overcome the heat added to the product by agitation is—

$$\text{Agitator B.t.u. per 24 hours} = \text{Horsepower of agitator} \times \text{2,544 B.t.u. per horsepower per hour}^{9} \times \text{Hours of agitator operation} \times \text{Motor efficiency}$$
$$= 3 \times 2{,}544 \times 16 \times 0.85$$

Table 6 shows that the total refrigeration needed in a 24-hour period for a 5-degree temperature change plus agitator load is 211,061 B.t.u. To convert the refrigeration load to tons, divide it by the number of hours of operation multiplied by 12,000:[10]

$$\frac{211{,}061}{16 \times 12{,}000} = 1.993 \text{ tons of refrigeration}$$

[9] One horsepower-hour is equivalent to 2,544 British thermal units (B.t.u.) per hour.

[10] 1 ton of refrigeration equals 12,000 B.t.u. per hour.

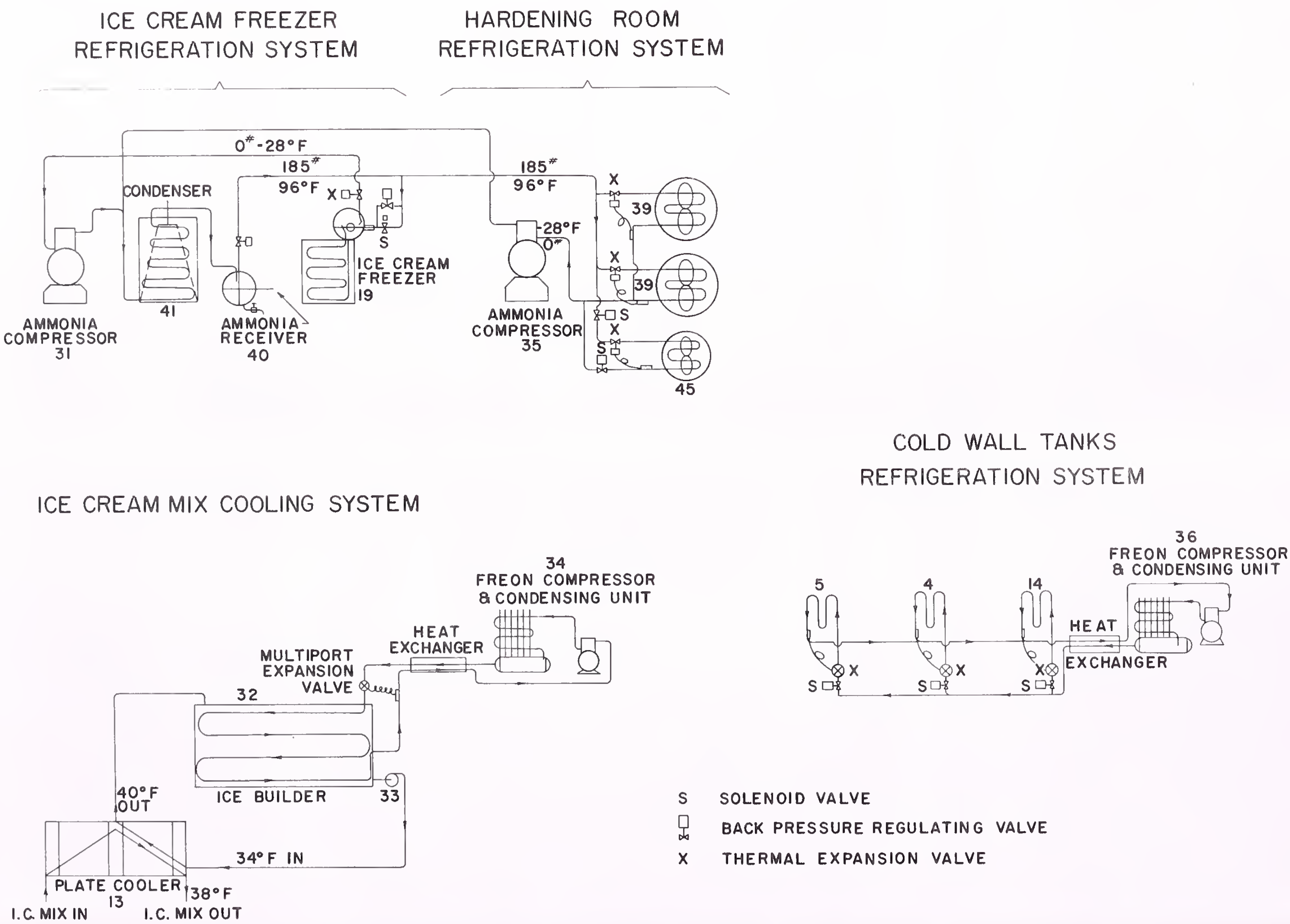


FIGURE 11.—Refrigeration system for an ice cream plant manufacturing 200,000 gallons annually.

TABLE 6.—*Refrigeration needed in 24-hour period to lower temperature of products in storage tanks from 41° to 38° F. and to overcome heat input of agitators, ice cream plant manufacturing 200,000 gallons of ice cream annually*

Tank No.	Product	Quantity of product	Weight of product per gallon	Temperature change[1]	Specific heat	Refrigeration needed to remove heat of products	Agitator load	Total refrigeration load
		Gallons	*Pounds*	*°F.*		*B.t.u.*	*B.t.u.*	*B.t.u.*
4	Cream	600	8.30	5	0.85	21,165	34,598	55,763
5	Concentrated skim milk	600	9.15	5	.95	26,078	34,598	60,676
14	Mix	1,600	9.15	5	.82	60,024	34,598	94,622
Total refrigeration needed						107,267	103,794	211,061

[1] 3-degree change in temperature of product + 2-degree rise caused by refrigeration loss through tank walls.

Pasteurized ice cream mix cooling requirements.—The plate heat exchanger (13) uses city water for initial cooling and 34° F. sweetwater for final cooling. It is suggested that an ice builder be used to supply the 34° sweet water.

The following is the formula for determining the amount of ice required:

$$\text{Pounds of ice required} = \frac{\text{Gallons of mix cooled per day} \times \text{Weight of 1 gallon of mix} \times \text{Specific heat} \times \text{Temperature change}}{\text{Latent heat of fusion of ice}}$$

The maximum amount of mix made in 1 day is eight batches, or 1,600 gallons. It is assumed that the city water precools the mix to 70° F. in the initial cooling section; therefore the ice builder must furnish refrigeration to cool the mix from 70° to 40° in the final section of the plate heat exchanger (13). The latent heat of fusion of ice is 144 B.t.u. per pound.

$$\text{Pounds of ice required} = \frac{1{,}600 \times 9.15 \times 0.82 \times 30}{144} = 2{,}501$$

Ten percent is allowed for agitation, pumping, and radiation losses, indicating that the minimum size for the ice builder would be 2,751 pounds. A 2,800-pound ice builder (32) is suggested.

To refrigerate the 2,800-pound ice builder over a 12-hour period would require a Freon compressor and condensing unit capable of developing the following capacity:

$$\text{Refrigeration required} = \frac{\text{Pounds of ice} \times \text{Latent heat of fusion of ice}}{\text{Hours of condensing unit operation} \times \text{12,000 B.t.u. per ton per hour}} = \frac{2{,}800 \times 144}{12 \times 12{,}000}$$
$$= 2.8 \text{ tons}$$

The minimum capacity of the condensing unit is 2.8 tons. A 5-horsepower condensing unit (34) is suggested.

Ice cream freezer refrigeration requirements.—Manufacturers of the 500-gallon-per-hour freezer specify that it should be used with an ammonia compressor rated 40.2 tons at 20 pounds suction pressure. The compressor would operate at zero pounds suction pressure, develop 15.4 tons of refrigeration at this suction pressure, and would require a 40-horsepower motor. A 15.4-ton, 40-horsepower ammonia compressor (31) is suggested.

Hardening room refrigeration requirements.—The refrigeration requirements of the hardening room are based on the refrigeration needed to (1) harden ice cream, (2) take care of air infiltration, and (3) compensate for losses through walls, ceiling, and floor and miscellaneous losses owing to body heat, electric lights, and electric motor loads. To determine the peak average hourly load for the room, it is necessary to calculate the peak average hourly load for each factor. In these calculations the peak average hourly load is computed for all factors except the heat gain from the ice cream entering the room. This is calculated as an average for 24 hours, since the heat dissipates from the ice cream over a prolonged period. Novelties purchased from outside sources do not contribute to the product load, as it is assumed that they are received at —20° F.

1. Heat gain from 2,750 gallons of ice cream entering the room may be determined by the following formula:

$$\text{B.t.u. per day} = \text{Gallons of ice cream per day} \times \text{350 B.t.u.}^{11} \text{ per gallon}$$
$$= 2{,}750 \times 350$$
$$= 962{,}500 \text{ B.t.u. per 24 hours}$$

[11] Standard industry practice.

The load per hour would be 40,104 B.t.u.

2. Heat gain from air infiltration is calculated by the following formula:

$$\text{B.t.u. per hour} = \text{Cubic feet of room} \times \text{Number of air changes per hour} \times \text{B.t.u. per cubic foot}$$

For a room of this size, it is estimated that four air changes per day, or 0.167 changes per hour, would occur owing to passage through doors, infiltration, and similar ways. To cool 1 cubic foot of air at 95° F. and 50 percent relative humidity to —20° and saturation (100 percent relative humidity) requires the removal of 4.27 B.t.u. per cubic foot. According to the formula, the heat gain from air infiltration for a room with an area of 1,060 square feet and a ceiling 8½ feet high (9,010 cubic feet) is 6,425 B.t.u. per hour (9,010 × 0.167 × 4.27).

3. Heat gain through walls, ceiling, and floor are calculated by the following formula:

$$\text{Heat gain through walls, floor, and ceiling, B.t.u. per hour} = \text{Surface area, square feet} \times \text{Coefficient of heat transmission}$$

The calculations are based upon a hardening room temperature of —20° F., and an outside temperature of 95°. An average overall coefficient of heat transmission for walls, floor, and ceiling of 4.33 B.t.u. per hour per square foot is suggested. A small portion of the hardening room is exposed to the 40° storage room, which has the same effect as an outside temperature of 40°, rather than 95°. For this condition the coefficient is 2.25 B.t.u. per hour per square foot.

The heat gain for the hardening room in this plant is—

Walls exposed to 95°F.	=(38.5+30+29+20) (8.5)	= 999
Ceiling exposed to 95°F.	=38.5×20+29×10	= 1,060
Floor exposed to 95°F.	=38.5×20+29×10	= 1,060
	Total surface	= 3,119 sq. ft.
Walls exposed to 40°F.	=(10.5+9.5) (8.5)	= 170 sq. ft.
Heat gain through walls, ceiling, floor, B.t.u. per hour	=3,119×4.33+170×2.25	=13,888

4. Miscellaneous losses include that from electrical energy and from workers in the room.

(a) It is assumed that there are three 150-watt electric lights on in the room. The formula for the heat gain from electric lights is—

$$\text{B.t.u. per hour} = \text{Total wattage of lights} \times \text{3.41 B.t.u. per watt}$$
$$= 450 \times 3.41 = 1{,}535$$

Each of the two refrigeration blowers (39) has a 3-horsepower motor. The formula for the heat gain from electric motors is—

$$\text{Heat gain from motors} = \text{Motor horsepower} \times \text{3,700 B.t.u. per hour}$$
$$= 6 \times 3{,}700 = 22{,}200 \text{ B.t.u. per hour}$$

(b) Only one worker is required in the hardening room. It is assumed that he works at a rate that will add 1,000 B.t.u. per hour to the refrigeration load.

The following is a summary of the heat gains in the hardening room:

	B.t.u. per hour
Ice cream entering room	40,104
Air infiltration	6,425
Walls, ceiling, and floor	13,888
Miscellaneous:	
Electrical energy	23,735
Personnel	1,000
Total	85,152
10 percent safety factor	8,515
Total design requirements	93,667

The above load is to be handled in a 16-hour operating cycle.

The capacity of the cooling units (39) is—

$$\text{Total cooling unit capacity} = \frac{\text{Hardening room load, B.t.u. per hour} \times 24 \text{ hours}}{12{,}000 \text{ B.t.u. per ton} \times 16 \text{ hours}} = \frac{93{,}667 \times 24}{12{,}000 \times 16}$$
$$= 11.70 \text{ tons}$$

Thus, the two cooling units should have a minimum capacity of 5.85 tons each. The cooling units suggested (39) have a capacity of 6.0 tons each at 8° F. temperature difference. They will therefore operate at zero pounds (—28° F.) suction pressure.

40° F. cold storage room.—The factors that determine the refrigeration requirements of the 40° F. cold storage room are (1) heat gain or refrigeration input through walls, ceiling, and floor; (2) heat gain through air changes in the room; (3) heat input from products entering the room; and (4) heat gain from electrical energy generated by lights and motors. A heat gain would also be incurred from a worker entering the room occasionally; however, for the proposed plant this would be only one person and usually only for a few moments. Thus, it is suggested that the 10-percent safety factor covers this situation. To determine the peak average hourly load for the room, it is necessary to calculate the peak average hourly load for each factor. It is assumed that all products received that are to be stored in the room are received in a refrigerated condition, and therefore this portion of the load is zero.

1. Heat input through walls, ceiling, and floor is calculated by the formula given for the hardening room. The 40° F. storage room is insulated with the same thickness of insulation as that used in the hardening room, so that should it become necessary to do so, the wall between the 40° F. room and the hardening room may be removed and this space added to the hardening room. For 40° inside and 95° outside, an average overall coefficient of heat transmission for walls, ceiling, and floor of 2.08 B.t.u. per hour is suggested.

		Sq. ft.
Outside walls	= (9 + 9) (8.5)	= 153
Ceiling	= 9 × 9	= 81
Floor	= 9 × 9	= 81
Total		= 315
	315 × 2.08	= 655 B.t.u. per hour

Heat loss to the hardening room was found to be 382 B.t.u. per hour. Subtracting this from the heat gain through the walls exposed to 95° F. outside air gives a net B.t.u. gain per hour of 273.

2. It is assumed that a room of this size would have 10 air changes per 24 hours, or 0.417 changes per hour. The coefficient for cooling the incoming air is 2.53 B.t.u. per hour per cubic foot. From the formula previously given:

Heat gain from air changes = 81 sq. ft. × 8.5 ft. (ceiling height) × 0.417 × 2.53 = 726 B.t.u. per hour

3. Products are refrigerated before they enter the cold storage room; therefore, this load is zero.

4. Heat gain from electrical energy is from lights and motors. One 100-watt light bulb and one ⅛-horsepower fan are the electrical load. From the formulas previously given:

		B.t.u. per hour
Heat gain from lights	= 100 × 3.41 =	341
Heat gain from motors	= 1/8 × 3,700 =	463
	Total =	804

The following is a summary of 40° F. storage room refrigeration losses:

	B.t.u. per hour
Wall losses	273
Air change losses	726
Product load	0
Electrical losses	804
Total	1,803

Allowing 10 percent for a safety factor indicates the design load for the 40° F. storage room would be 1,983 B.t.u. per hour (1,803 + 180 = 1,983).

For a 16-hour duty cycle (8 hours off), the 40° F. storage room blower (45) must have the following capacity (formula previously given in calculations for hardening room):

$$\frac{1{,}983 \times 24}{12{,}000 \times 16} = 0.25 \text{ ton}$$

The 40° F. storage room cooling unit (45) suggested has a capacity of 0.27 tons at 10° temperature difference between the refrigerant and the air being cooled.

The total load to be handled by ammonia compressor 35 is the hardening room plus the 40° F. storage room, or 11.93 tons at zero suction pressure. An ammonia compressor developing 12.3 tons at zero pounds suction pressure driven by a 30-horsepower motor is suggested.

Heating System

The heating system in this plant is planned to take care of the load for (1) heating water for cleaning operations, (2) heating the building during cold weather, (3) producing steam for the pasteurizing system, and (4) allowing (20 percent) for heat loss owing to radiation, insulation loss, and any other heat losses not otherwise provided for.

It is assumed that the maximum hot water requirements would be 400 gallons per hour and that the incoming water must be heated 50° F. The boiler horsepower required is—

$$\text{Boiler horsepower for heating water}^{12} = \frac{\text{Gallons of water per hour} \times \text{Weight of 1 gallon of water} \times \text{Specific heat} \times \text{Temperature change}}{35{,}000}$$

$$= \frac{400 \times 8.3 \times 1.0 \times 50}{35{,}000} = 4.75$$

The building heating load is calculated at 100,000 B.t.u. per hour per 1,500 square feet[13] of area to be heated. This includes all areas except the boiler-refrigeration room, which is heated by boiler radiation and motor heat, and the refrigerated storage areas. The following are the areas to be heated:

	Square feet
Office and hall	300
Dry storage	645
Restrooms and lockers	122
Laboratory	72
Processing and freezing room	1,220
Customers' and drivers' room	165
Cabinet shop	310
Total	1,834

[12] A boiler horsepower is 33,524 B.t.u., the amount of heat necessary to evaporate 34.5 lb. of water, but for calculations the industry uses 35,000 B.t.u.

[13] Formula used by heating and ventilating manufacturers to estimate heating requirements for dairy plants in northern sections of the United States.

The formula for determining the boiler horsepower for heating the building areas is—

$$\text{Boiler horsepower for heating building} = \frac{\text{floor area} \times 100{,}000}{1{,}500 \times 35{,}000}$$
$$= \frac{2{,}834 \times 100{,}000}{1{,}500 \times 35{,}000} = 5.39$$

The pasteurizing heating load comes from the two 200-gallon pasteurizers (10, 11). These pasteurizing vats alternate heating and 30 minutes is allowed to heat 200 gallons of mix to pasteurizing temperature. The following is the boiler horsepower required for pasteurizing:

$$\text{Boiler horsepower for pasteurizing} = \frac{\text{Gallons of mix heated per hour} \times \text{Weight of gallon of mix} \times \text{Temperature change} \times \text{Specific heat}}{35{,}000}$$
$$= \frac{400 \times 9.15 \times 127 \times 0.82}{35{,}000} = 10.9$$

The total heating requirements are 21.04 boiler horsepower plus 20 percent for losses, or 25.25 boiler horsepower. A 50-horsepower boiler is recommended, which allows for additional capacity to handle the first few minutes of heating the vat pasteurizers when the steam in-rush is very high.

Ventilating and Air-Conditioning System

The processing and freezing room, cabinet shop, dry storage room, offices, laboratory, lockers, and restrooms are ventilated by a roof-mounted air-circulating and heating unit (53). Air, returned from the plant through ducts in the ceiling, is mixed with fresh outside air, filtered, heated, and returned to the plant via ducts.

The processing and freezing room should have one complete air change every 3 minutes to keep humidity down. Other areas have air changes every 7 minutes. The plant operates under slight positive air pressure, which reduces the entry of nonfiltered air.

Dampers controlled by a modulating motor and a thermostat automatically control the temperature of air going to the heating coil. Final air temperature is controlled by a thermostat, which modulates the steam input to the heating coil. High fan speed is used for summer ventilation when all air comes from the outside and no air is recirculated.

The office areas are air conditioned in summer by window air-conditioning units (not shown).

Plant Manufacturing 1,250,000 Gallons of Ice Cream and Novelties a Year

Refrigeration System

It is suggested that the following principal refrigeration equipment be located in the refrigeration equipment room: Ammonia receiver (62), 30-ton, 40-hp. booster compressor (63), 69-ton, 60-hp. booster compressor (64), 53-ton, 75-hp. second-stage compressor (65), 75.4-ton, 125-hp. second-stage compressor (66), ammonia intercooler (67), 5-hp. air compressor (88), and electric panel board (68).

Also part of the refrigeration system, but located elsewhere, are the 12,000-pound ice builder (52), 2.0-ton, 40° F. cooling unit (61), 5.5-ton, —20° cooling units (60), and 130-ton evaporative condenser (76).

To maintain the three temperatures required, the refrigeration system suggested is divided into three temperature ranges, and therefore into three ammonia suction pressures. In refrigeration, it is not the volume of gas pumped or the piston displacement of the compressors that determines the useful cooling effect; rather, it is the weight of the refrigerant evaporated. If the pressure (and consequently the refrigerant temperature in the cooling coils) is lowered, the volume of a unit weight of the refrigerant increases greatly out of proportion to the change in pressure. A standard single-stage ammonia compressor producing 1 ton of refrigeration at 20 pounds suction pressure and 175 pounds condensing pressure would require 1 horsepower. If this same machine were operated at zero pounds suction pressure and 175 pounds condensing pressure, only 0.326 tons of refrigeration would be produced, requiring 0.552 horsepower, or an increase of 80 percent in horsepower per ton of refrigeration. With a two-stage operation the increase in displacement and power requirements is not as pronounced. At zero pounds suction pressure and 175 pounds condensing pressure a two-stage compression system uses about 19 percent less power than a single stage. Two-stage systems reduce the compression ratio, thus increasing the volumetric efficiency and resulting in an overall reduction in piston displacement.

The three suction pressures and the equipment operated at these pressures are shown diagrammatically in figure 12.

The following are the suction pressures and machinery operated at these pressures:

7 inch Vacuum, −37.8° F.
- Brine shell cooler (59)

Zero pounds, −28° F.
- Hardening room cooling units (60)
- 900-g.p.h.-ice cream freezer (38)
- 180-g.p.h.-ice cream freezer (40)

25 pounds, 11.3° F.
- 12,000-pound ice builder (52)
- 40° F. cooling unit (61)
- 1,500 gallon cream tank (4)
- 1,500-gallon concentrated skim milk tank (5)
- 1,500-gallon mix storage tanks (30, 31, 32)

Brine shell cooler.—The novelty tank makes 500 dozen novelties per hour. Water ice novelties have the greatest refrigeration requirements. At the above operating rate, 180 gallons of water ice mix are required. The total refrigeration load is the sum of the following individual loads, in B.t.u. per hour: (1) Heat input from pumping brine, (2) heat input from molds, (3) heat input from exposure of brine room, (4) heat input from removal of product's sensible heat, and (5) heat input from removal of latent heat in product.

1. Two 5-horsepower pumps circulate cold brine through the novelty tank. Assuming that they operate at 85 percent efficiency, the heat

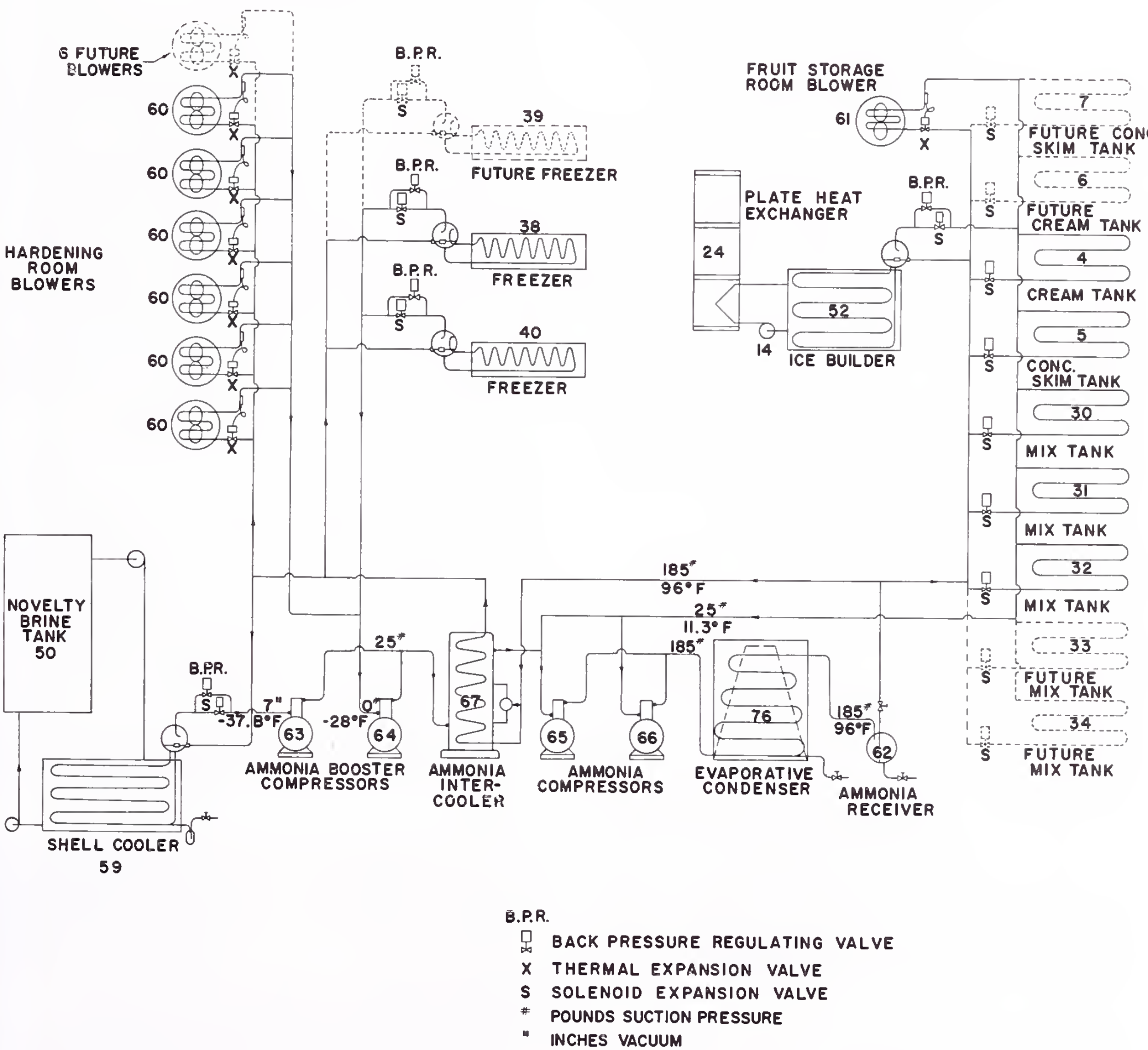


FIGURE 12.—Refrigeration system for an ice cream plant manufacturing 1 million gallons of ice cream and 250,000 gallons of novelties annually.

input to the brine from these pumps would be—

$$\text{Heat input from pumps} = \text{Horsepower of pumps} \times \text{Pumping efficiency} \times 2{,}544 \text{ B.t.u. per hp.-hr.}$$
$$= 10 \times 0.85 \times 2{,}544$$
$$= 21{,}624 \text{ B.t.u. per hour}$$

2. The novelty tank manufacturer specifies that 6 B.t.u. is required to chill each mold from fill temperature to the brine temperature of —34° F. The heat input from molds would be—

$$\text{Heat input from molds} = \text{No. of molds per hour} \times 6 \text{ B.t.u. per mold}$$
$$500 \times 12 \times 6 = 36{,}000 \text{ B.t.u. per hour}$$

3. The heat input from exposure of the brine surface to room temperature has been determined by the novelty tank manufacturer to be 48,000 B.t.u. per hour.

4. Heat input from the product's sensible heat is the heat removal necessary to cool the product from the temperature at which it comes out of the freezer (28° F.) to the temperature to which it is cooled by the brine (—15° F.), not including the freezing of any water in the product. Specific heat is 0.90. The formulas for finding the weight of the product and the product's sensible heat are—

$$\text{Weight of product} = \text{180 gallons per hour} \times \text{9.415 pounds per gallon} = \text{1,695 pounds per hour}$$

$$\text{Product's sensible heat} = \text{Weight of product (pounds per hour)} \times \text{Temperature range} \times \text{Specific heat}$$
$$= 1{,}695 \times 43 \times 0.90$$
$$= 65{,}597 \text{ B.t.u. per hour}$$

5. The mix for the water ice novelty is 67 percent water. When the temperature of the novelty is reduced to —15° F., 90 percent of the water is frozen. The latent heat must be removed from the product to freeze this water.

$$\text{Product's latent heat} = \text{Weight of product (pounds per hour)} \times \text{Percent frozen} \times \text{Percent water in product} \times \text{Latent heat of fusion of water}^{14}$$
$$= 1{,}695 \times 0.90 \times 0.67 \times 144$$
$$= 147{,}126 \text{ B.t.u. per hour}$$

The total refrigeration requirements for the 7-inch vacuum system is the sum of the above loads:

Heat input from —	*B.t.u. per hour*
(1) Pumps	21,624
(2) Molds	36,000
(3) Exposure	48,000
(4) Product's sensible heat	65,597
(5) Product's latent heat	147,126
Total	318,347
10% allowance for miscellaneous losses and safety factor	31,835
	350,182

$$\text{Tons of refrigeration required} = \frac{350{,}182}{12{,}000} = 29.2$$

Hardening room.—The hardening room is 71 feet long, 50 feet wide, and 13 feet 8 inches high. Its temperature is maintained at —20° F. by six cooling units, each of which is equipped with a 3-horsepower fan. On a peak day, 6,750 gallons of ice cream enter the room at 22° F. and must be cooled to —20°. The total refrigeration load of the hardening room is the sum of the heat input (1) through walls, ceiling, and floor, (2) from ice cream and novelties entering room, (3) from wire baskets entering room, (4) from air changes in room, (5) from electric motors in room, (6) from electric lights in room, and (7) from workers in room.

Selection of refrigeration equipment should be based upon the peak average hourly load for each of the above factors, with the exception of the product and basket loads. The ice cream, hardened in a 12-hour period, enters the room over a period of about 8 hours. The load varies, since the heat given up is not the same for the first hour as it is for the last one. Therefore, it is suggested that an average for the 12-hour period be used. Selection of the compressor and room cooling unit is based on a 24-hour-per-day operation. Since the product load approximates one-third of the total load, there is sufficient time for room defrosting when the product hardening period is over. Furthermore, the use of multiple cooling units allows the defrosting of one cooling unit at a time. The hardening room loads, the formulas for determining them, and the results of these determinations are listed in the order previously given.

1. Heat input through walls, ceiling, and floor is calculated by the formula shown below. The calculations are based on a hardening room temperature of —20° F. and an outside temperature of 95°. An average overall coefficient of heat transmission for walls, floor, and ceiling of 4.33 B.t.u. per hour per square foot is suggested for walls insulated with 8 inches of cork or equivalent. The cold room for the suggested plant would have a surface area of—

[14] Latent heat of fusion for water is 144 B.t.u. per pound.

		Square feet
Walls	$=71\times12\times2+50\times12\times2=$	2,904
Ceiling	$=71\times50$ =	3,550
Floor	$=71\times50$ =	3,550
	Total =	10,004

The formula is—

$$\text{Heat gain through walls, floor, and ceiling} = \text{Surface area (square feet)} \times \text{Coefficient of heat transmission}$$
$$=10{,}004\times4.33=43{,}317 \text{ B.t.u. per hour}$$

2. Heat gain from 6,750 gallons of ice cream entering the room may be determined by the following formula:

$$\text{Heat gain from ice cream per 12-hour day} = \text{Gallons of ice cream per day} \times \text{350 B.t.u. per gallon}$$
$$=6{,}750\times350=2{,}362{,}500 \text{ B.t.u.}$$

The load would be 196,875 B.t.u. per hour.

Since the novelties enter the room at —15° F., and total weight is small in comparison to that of the ice cream, this load may be included with the 10-percent safety factor.

3. On an average July day, 1,100 wire baskets weighing 10 pounds each enter the hardening room at 95° F.; the specific heat of each basket is 0.2. Heat input from the wire baskets is determined by the following formula:

$$\text{Heat input from wire baskets} = \text{Weight of baskets entering} \times \text{Specific heat} \times \text{Temperature change}$$
$$=11{,}000\times0.2\times115$$
$$=253{,}000 \text{ B.t.u. per 12 hours}$$
$$=21{,}083 \text{ B.t.u. per hour}$$

4. For a room of this size, it is estimated that 1.8 air changes per day, or 0.075 changes per hour, would occur because of passage through doors and infiltration. Cooling 1 cubic foot of air at 95° F. and 50 percent relative humidity to —20° and saturation, requires the removal of 4.27 B.t.u. per cubic foot. Heat gain from air infiltration is calculated by the following formula:

$$\text{Heat gain from air infiltration} = \text{Cubic foot of room} \times \text{No. of air changes per hour} \times \text{B.t.u. per cubic foot}$$
$$=71\times50\times12\times0.075\times4.27$$
$$=13{,}643 \text{ B.t.u. per hour}$$

5. Heat gained from electric motors consists of the electrical energy input from the fan motors and overhead conveyor drive motors. Six cooling units with 3 horsepower in each unit operate continuously. The overhead conveyor system is operated by four 3/4-horsepower motors. The formula for heat input from motors is—

$$\text{Heat input from motors} = \text{Motor horsepower}\times3{,}700 \text{ B.t.u. per hour}$$
$$=(6\times3)+(4\times3/4)\times3{,}700$$
$$=77{,}700 \text{ B.t.u. per hour}$$

6. There are ten 100-watt electric lights used to illuminate the hardening room. The heat gain from lights is—

$$\text{Heat input from lights} = \text{Total wattage of lights} \times 3.41 \text{ B.t.u. per watt per hour}$$
$$=10\times100\times3.41=3{,}410 \text{ B.t.u. per hour}$$

7. Only two workers will be required in the hardening room, and they will work at a rate which adds 1,000 B.t.u. per hour for each man. The total heat input for two men would be 2,000 B.t.u. per hour.

The total peak average hourly load for the hardening room would be the total of the above factors.

	B.t.u. per hour
(1) Walls, ceiling, and floor	43,317
(2) Ice cream entering room	196,875
(3) Baskets entering room	21,083
(4) Air infiltration	13,643
(5) Electric motors	77,700
(6) Electric lights	3,410
(7) Personnel	2,000
Total	358,028
10% safety factor	35,803
Total design requirements	393,831

Tons of refrigeration required for the hardening room $=\frac{393{,}831}{12{,}000}=32.8$

The six cooling units suggested (60) have a capacity of 5.5 tons each at 8° F. difference between the room temperature and refrigerant temperature.

Ice cream freezers.—Manufacturers recommend 28.6 tons of refrigeration for the large freezer (38) and 7.3 tons for the small one (40) at zero pound suction pressure, a total of 35.9 tons.

Ice builder.—The ice builder is to supply 34° F. water for cooling ice cream mix on plate heat exchanger (24) at 25-pound suction pressure. The peak load is 3,850 gallons per day, which must be cooled from 94° F. to 40°. The following is the formula for determining the pounds of ice required:

$$\text{Pounds of ice required} = \frac{\text{Gallons of mix cooled per day} \times \text{Weight of 1 gallon of mix} \times \text{Specific heat} \times \text{Temperature change}}{\text{Latent heat of fusion of ice}} = \frac{3{,}850\times9.15\times0.82\times54}{144} = 10{,}832$$

10% allowance for agitation and pumping losses	1,083
Pounds of ice recommended	11,915

A 12,000-pound ice builder is suggested for the above load. The ice is to be built up over a 12-hour period. The formula for determining the tons of refrigeration required is—

$$\text{Tons of refrigeration} = \frac{\text{Pounds of ice} \times \text{latent heat of fusion of ice}}{\text{Hours of condensing unit operation} \times \text{12,000 B.t.u. per ton per hour}}$$

$$= \frac{12{,}000 \times 144}{12 \times 12{,}000} = 12.0$$

40° cold storage room.—The refrigeration load for the 40° F. cold storage room is made up of heat or refrigeration input (1) through walls, ceiling, and floor, (2) through air changes, (3) from products entering room, and (4) from electrical energy. Formulas for determining the peak average hourly loads for the above factors have been given for the hardening room.

Assuming 95° F. outside temperature and 50 percent relative humidity, the heat input due to air change is 2.61 B.t.u. per cubic foot. It is assumed that there will be 5 air changes each 24 hours or 0.208 changes per hour. The room is to be insulated with 4 inches of corkboard or equivalent. The inside ceiling height is 8½ feet; outside height is 10 feet. The heat gain per 24 hours for 95° F. outside temperature is 99.0 B.t.u. per square foot, or 4.12 B.t.u. per hour.

For a room this size, two 150-watt bulbs would be in use. The refrigeration blower (61) is equipped with a ½-horsepower fan.

Using the formulas given for the 200,000-gallon plant results in a peak average hourly load of 11,613 B.t.u. for the 40° F. storage room.

1. Heat input through walls, ceiling, and floor is calculated by the formula given for the hardening room. Since the refrigeration gain from the surface exposed to the hardening room is small in terms of the total load, it is ignored in these calculations.

		Square feet
Walls	$= (29.25 + 29.25 + 13.25 + 13.25)\ 8.5 =$	722
Ceiling	$= 29.25 \times 13.25 =$	388
Floor	$= 29.25 \times 13.25 =$	388
	Total =	1,498

Heat input through walls, ceiling, and floor $= 1{,}498 \times 4.12$
$= 6{,}172$ B.t.u. per hour

2. Heat input from air changes may be determined by the formula given for the hardening room.

Heat input from air changes $= 388$ sq. ft. $\times 8.5$ ft. $\times 2.61 \times 0.208 = 1{,}790$ B.t.u. per hour

3. The heat gain from products entering the room is zero, since it is assumed that these products are refrigerated when received.

4. Heat input from electrical energy may be determined from the formula given for the hardening room:

		B.t.u. per hr.
Electric lights	$= 2 \times 150 \times 3.41 =$	1,023
Electric motor	$= 1/2 \times 3{,}700 =$	1,850
	Total =	2,873

The following is a summary of the 40° F. storage room refrigeration losses:

	B.t.u. per hr.
Walls, ceiling, and floor losses	6,172
Air change loss	1,790
Product load	0
Electric losses	2,873
Total	10,835
10% for miscellaneous losses and safety factor	1,083
Total design load	11,918

This load is to be handled on a 16-hour duty cycle which allows 8 hours for the refrigeration to be turned off and for defrosting. The tons of refrigeration required are—

$$\frac{11{,}918 \times 24}{16 \times 12{,}000} = 1.49 \text{ tons}$$

The cooling unit suggested (61) has a capacity of 2.0 tons at 10° F. temperature difference between the refrigerant and the air being cooled.

Cold-wall tanks.—The formula for determining refrigeration required for cold-wall tanks has been given for the 200,000-gallon ice cream plant. There are five 1,500-gallon tanks in the 1,250,000-gallon plant that require refrigeration: Cream tank (4), concentrated skim milk tank (5), and mix storage tanks (30, 31, 32).

It is assumed that products enter these tanks at 41° F. and are to be cooled to 38° F. in a 16-hour period. The heat gain from the room is assumed to be 2° per 24 hours. This results in a total of 5° temperature change. The specific heat of concentrated skim milk is 0.95; for cream it is 0.85; and for ice cream mix, 0.82. The weights per gallon are 9.15 pounds for skim milk and ice cream mix and 8.30 pounds for cream.

It is estimated that the 1-horsepower agitators will operate 16 hours a day at 85 percent efficiency.

Table 7 shows that the total refrigeration needed in a 24-hour period is 459,917 B.t.u. To convert the refrigeration load to tons, divide it by the number of hours of operation multiplied by 12,000:

$$\frac{459{,}917}{16 \times 12{,}000} = 2.39 \text{ tons}$$

Ammonia compressor.—Following is a summary of the tons of refrigeration required for the plant at the three suction pressures:

	Tons
7″ Vacuum, −37.8° F.:	
Brine shell cooler	29.2
Zero pound, −28° F.:	
Hardening room	32.8
Ice cream freezers	35.9
Total	68.7
25 pounds, 11.3° F.:	
40° F. cooling units	2.00
Cold-wall tanks	2.39
Ice builder	12.00
Total	16.39

Two booster compressors are needed: The first, to handle 29.2 tons of refrigeration from 7 inches of vacuum to 25 pounds of pressure for the novelty tank operation; the second, to handle 68.7 tons from zero to 25 pounds of pressure for the hardening room and ice cream freezers. For 29.2 tons of refrigeration, 7 inches of vacuum compressed to 25 pounds of pressure, 28.7 brake horsepower are required. A 30-ton, 40-horsepower booster compressor is suggested (63). A 40-horsepower motor is recommended, because during startup of the novelty tank the brine is warmer, resulting in a rise in suction pressure which requires more power to handle. For 68.7 tons of refrigeration, zero pound compressed to 25 pounds pressure, 51.4 brake horsepower are required. A 69-ton, 60-horsepower, two-speed booster compressor (64) is suggested.

The discharge from the booster compressors is piped to ammonia intercooler (67), which removes the heat of compression (superheat) and subcools the liquid ammonia flowing to the process equipment to which the booster compressors are connected.

The second-stage compression of 25 to 185 pounds handles the load from the booster compressors, ammonia intercooler, and the 16.39-ton load (fruit room, cold-wall tanks, and ice builder). Manufacturers' tables indicate that a factor of 1.150 applies to the 7-inch vacuum load and 1.116 to the zero pound load. These factors account for the heat of compression and subcooling of liquid ammonia in the intercooler. Therefore, the total second-stage compression load is—

	Tons
29.2 × 1.150	33.58
68.7 × 1.116	76.67
25 pound load	16.39
Total	126.64

To handle the above second-stage load, two compressors are recommended. The first compressor suggested (65) has a capacity of 53 tons and requires 74.1 brake horsepower when discharging at 185 pounds pressure. Therefore, a 75-horsepower motor is suggested. The second compressor suggested (66) would have a capacity of 75.4 tons and require 105.2 brake horsepower. Therefore, a 125-horsepower motor is suggested.

A 130-ton evaporative condenser (76) can handle the total refrigeration system.

How the refrigeration system operates.—The refrigeration system operates automatically at night when the only loads are the hardening room, fruit room, ice builder, and cold-wall

TABLE 7.—*Refrigeration needed in 24-hour period to lower temperature of products in storage tanks from 41° to 38° F. and to overcome heat input of agitators, ice cream plant manufacturing 1,250,000 gallons of ice cream annually*

Tank number	Product	Quantity of product	Weight of product per gallon	Temperature change[1]	Specific heat	Refrigeration needed to remove heat of products	Agitator load[2]	Total refrigeration load
		Gallons	*Pounds*	*°F.*		*B.t.u.*	*B.t.u.*	*B.t.u.*
4	Cream	1,500	8.30	5	0.85	52,913	34,598.4	87,511.4
5	Concentrated skim milk	1,500	9.15	5	.95	65,194	34,598.4	99,792.4
30, 31, 32	Mix	4,500	9.15	5	.82	168,818	103,795.2	272,613.2
Total refrigeration needed						286,925	172,992.0	459,917.0

[1] 3-degree change in temperature of product + 2-degree rise caused by refrigeration loss through tank walls.
[2] See formula for computing agitator load on p. 35.

tanks. This load is approximately 48 tons; it is handled by setting the 69-ton booster compressor on half speed. At this speed the compressor will develop 34.5 tons of refrigeration for the hardening room. The second-stage compression is handled by the 53-ton compressor (65). The hardening room refrigeration is controlled by a room thermostat, which automatically starts and stops booster compressor 64.

The ice builder (52) is equipped with an ice thickness control. When the proper amount of ice is built up on the coils, the ammonia automatically passes through a back-pressure regulating valve set at 30° F., preventing any additional buildup of ice.

The cold-wall tanks are equipped with thermostats attached to the outside of the inner jacket. When the product temperature drops to a predetermined point, a solenoid valve in the ammonia feed line shuts off, and cuts off the refrigeration. The agitator is also automatically shut off at this point.

The second-stage compressor (65) is equipped with controls to reduce the output 50 percent whenever the hardening room does not require refrigeration.

During plant operation, the ammonia compression equipment is operated manually. The booster compressor (64) is on high speed, since it handles both the ice cream freezer and hardening room loads.

The hardening room blowers (60) are of the electric defrost type and may be defrosted individually while the other five units are in operation.

Heating System

The heating system in this plant is essentially the same as that in the smaller plant. The formulas for computing the load on the heating system are also the same.

The boiler horsepower for the heating system is 7.11. This estimate is based on the formula for hot water requirements and the assumption that the maximum requirement is 600 gallons of hot water per hour.

The building heating load is calculated at 100,000 B.t.u. per hour per 1,500 square feet of heated floor area. All areas would be heated except the boiler room and refrigeration equipment room heated by radiation and motor heat, respectively, and the refrigerated storage areas.

The areas to be heated are—

	Square feet
General office	1,600
Private offices, five	921
Lavatories, four	384
Locker rooms, three	424
Plant entrance	228
Lunch room	340
Laboratory	214
Receiving shelter	1,282
Dry storage	3,062
Paper storage	2,722
Mix assembly room	1,218
Freezing and packaging room	3,645
Kitchen	378
Total	16,418

Heating the 16,418 square feet requires 31.27 boiler horsepower.

The pasteurizing heating load is the steam required to heat the plate pasteurizer (24) and the steam infuser heater (20). The plate pasteurizer heats the mix from 146° to 180° F. and the steam infuser from 180° to 230°. Thus the total heating range is 84°. The heating load for the pasteurizer and steam infuser heater is 10.80 boiler horsepower.

The total of the heating loads for this plant is 49.18 boiler horsepower. Allowing 20 percent for radiation and other losses, 59.02 boiler horsepower are required. Two 50-boiler horsepower boilers are suggested to provide for standby capacity, since this plant will process mix 5 days a week.

Ventilating and Air-Conditioning System

The various plant areas are heated and ventilated by two roof-mounted air-circulating and heating units. Air returned from the plant through ducts in the ceiling is mixed with fresh outside air, filtered, heated, and returned to the plant via ducts.

The mixing and freezing areas will have one complete air change every 3 minutes, to control humidity. Other areas have air changes approximately every 7 minutes. The plant operates under slight positive air pressure, which reduces the entry of nonfiltered air through the doorways.

Dampers are controlled by a modulating motor and thermostat, which automatically control the temperature of the air going to the heating coil. Final air temperature is controlled by a thermostat, which modulates the steam input in the heating coil. High speed is used on the fan for summer ventilation when all air comes from the outside and no air is recirculated.

The office areas and locker rooms are cooled in summer by an air-conditioning unit located in a small room in the office area.

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